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WORKING PAPER 2017:27

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ISSN 1651-1166

# Student Aid, Academic Achievement, and Labor Market Behavior

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December 13, 2017

**Abstract:** How does the financial aid allocation mechanism affect student behavior? We provide a framework for quantifying the impact of financial aid on student debt, academic capital, and labor market outcomes. We specify and estimate a dynamic discrete choice model of simultaneous education, work, and student loan take-up decisions. We use administrative panel data and exploit exogenous variation from the 2001 Swedish Study Aid reform to estimate the model. The reform reduced the cost of working while enrolled, resulting in a 14 percentage points increase in students working during the academic year. The reform also increased (decreased) the cost of borrowing for low (high) earners. This decreased the share of low expected earners not taking up student loans by 2 percentage points, and increased the share of high expected earners taking up the full loan by 2 percentage points. The estimated model enables ex-ante evaluation of various changes to financial aid packages. We find that front-loading debt repayment – by increasing income-contingency or shortening the loan repayment period – reduces debt and lowers academic capital accumulation as students finance more of the college cost by working and less by taking-up loans. Income-contingency of repayments exhibits and elasticity of -0.72 for debt and -0.14 for income at exit, but is marginally decreasing. Changing the grant/loan composition of aid has little impact on human capital accumulation, but large impacts on student debt. This means that the government largely can decide who bears the college cost without affecting human capital accumulation.

JEL: D90, H52, I21, I22, I28, J22, J24, J31.
Keywords: Student Aid, Education and Labor Market Outcomes, Dynamic Discrete Choice.

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We thank Stephane Bonhomme, Flavio Cunha, Ingvil Gaarder, Steve Levitt, Lars Ljungqvist, Elena Manresa, Magne Mogstad, Mårten Palme, Melissa Tartari, Alessandra Voena, Ken Wolpin, Björn Öckert, and seminar participants at Copenhagen Business School, UCLouvain, IFAU Uppsala, IFS London, IFN Stockholm, IIES Stockholm, NHH Norwegian School of Economics, SOFI Stockholm, SSE, University of Bergen, University of Chicago, University of Edinburgh, University of Pennsylvania, University of Wisconsin-Madison, University of Calgary, Aarhus University, ISER Essex, University of Cagliari, EIEF, UTS, Uppsala University, University of East Anglia, and various conferences. We are immensely grateful to IFAU for sharing their data. We also thank Nina Jalava, Patrick Liu, and Svante Midander for research assistance, Jörgen Moen for assistance with the data and the servers, and the CSN staff for providing us with all the details of the Swedish study aid scheme. We gratefully acknowledge financial support from the Swedish Research Council (VR) and Mattana also from the Jan Wallander och Tom Hedelius Research Foundations and FNRS (Fonds de la Recherche Scientifique) Belgium (Research Project PDR T.0044.13). The usual disclaimers apply.

# 1 Introduction

How does the financial aid allocation mechanism affect student behavior? Despite the large amounts of financial aid to students attending higher education, little is known about the effects of aid on human capital formation. In this paper, we estimate a structural dynamic model of how implicit incentives in financial aid packages affect behavior and human capital accumulation – both education and labor market experience – during college enrollment *and* how these relate to long-term earnings capacity. We use the model to analyze how financial aid can be allocated more cost-effectively to obtain declared social goals such as increase college graduation rates and the speed at which individuals graduate, while at the same time keep student debt at manageable levels and take its distributional effects into account. To the best of our knowledge, this is the first paper to provide a unified empirical framework to answer highly policy relevant questions like: What if we change the share of grants relative to loans? What if we change the way loans are repaid? What if we change the means-testing?

These are challenging empirical questions to answer, since they depend on individual budget constraints, which individuals are close to college enrollment and graduation margins, and how strongly they respond to financial incentives. Sweden provides an ideal environment to analyze study aid policies, because we directly observe individual budget sets *and* have exogenous variation in budget sets. The uniformity of study aid rules in Sweden and the detailed administrative panel data enable us to model important aspects of student choices and outcomes, while both taking their simultaneous and sequential nature into account. A reform of the Swedish study aid scheme in 2001 provides us with quasi-experimental variation that affects both current and intertemporal trade-offs.

Student aid in Sweden is universal and administered by a central study aid authority. On top of uniformly zero tuition, maximum yearly study aid is around SEK 100,000 (around USD 12,000) for all eligible students.[1] Around one third of this amount is a grant and the remaining two thirds are provided as a loan.[2] In 2001, four main aspects of the Swedish study aid scheme changed: the grant share increased, the loan repayment changed from an income-contingent (IC) to an annuity-based plan, the eligibility rules became more stringent, and the means testing was relaxed – effectively reducing the implicit income tax for students. The increased grant share

[1] Source: Centrala Studiestödsnämnden (CSN) as of 2017.

[2] Throughout grants can be thought of as any non-repayable monetary transfer to the students conditional on college enrollment; e.g any scholarship or negative tuition costs. We will refer to the amount of grant relative to the total aid amount (grant plus loan) as the *grant share*.

lowered student debt and decreased both the extensive and intensive margin of student labor supply for students working few hours. The means-testing only affected the intensive margin of student labor supply for students working more hours, while the change in loan repayments affected the intertemporal consumption trade-off by increasing the cost of borrowing for low earners and decreasing it for high earners. We find that students financed more of their college cost through labor income and less through debt after the reform – this shift was largest for low expected earners. The fraction of students working during the academic year increased by 14 percentage points. The fraction of low expected earners not taking up student loans increased by 2 percentage points, and the fraction of high expected earners taking up the full loan increased by 2 percentage points.

We specify and estimate a dynamic discrete choice model of joint education, work, and loan take-up decisions of college students. The model embeds how these choices affect college productivity (in terms of how many course credits and degrees are accumulated) and labor market productivity (in terms of labor income). Students stay enrolled as long as their expected degree premium exceeds the opportunity cost of staying enrolled. Students derive consumption from college enrollment and three sources of income: grants, loans, and labor income. Grants lower the direct cost of enrollment. Loans also lower the direct college cost; however, they introduce a trade-off between current and future consumption as loans need to be repaid after college exit and thus lower future consumption. Different repayment plans entail different intertemporal trade-offs. For example, an income-contingent loan is a proportional tax on future labor income that reduces the value of graduating and taking a high-paid job; on the other hand, it also ensures that those who get bad income draws after college bear a lower cost of college. Working lowers current opportunity costs of enrollment, but increases future opportunity costs of enrollment through increased labor market experience. Working can also increase the direct costs by lowering the means-tested study aid. Finally, working may even decrease the consumption value of education and decrease future opportunity costs to the extent that there are adverse effects on academic achievement. Importantly, we allow for different trade-offs between working and academic achievement depending on whether the student works during the summer or during the semesters.

We exploit the exogenous variation from the 2001 reform and administrative panel data of the Swedish population of high school graduates in 1994-2002, to estimate the parameters of the model. Our empirical strategy combining a structural dynamic model and a quasi-experiment has four main advantages: First, key model parameters are estimated exploiting the exogenous variation in the data, thus we do not rely as heavily on potentially endogenous wage variation and functional form assumptions. Second, it allows us to estimate a richer model, including the intertemporal elasticity of substitution (IES) parameter in the utility function. Third, it enables us to go beyond ex-post evaluation of total effects and to disentangle the mechanisms by which specific parts of the study aid scheme affect debt accumulation, academic achievement, and labor market behavior. Fourth, we are able to simulate the ex-ante effects of various potential policy reforms of the study aid scheme. The idea of combining a quasi-experiment with a structural dynamic model has been strongly advocated but has not previously been implemented in an analysis of the impact of student loans.[3]

The estimation of the model accounts for self-selection of student employment and loan take-up – based on both observed and unobserved heterogeneity – and dynamic selection in terms of who drops out and graduates when. Our estimated model fits the observed patterns in the data well. We also assess model fit along several dimensions of heterogeneity that we do not model: field of study, parental education and income, coresidence with parents, city cost-of-living (CLI), and gender. This corroborates that these dimensions of heterogeneity are not causing systematic bias in our predictions and lends more credence to external validity of our results for different subgroups and populations. For example, CLI varies greatly across Swedish cities, such that the fraction of living costs covered by study aid also varies as the total aid amount is uniform. The fact that we fit the differences by CLI makes us confident that the model is rich enough to capture the underlying reasons why students facFing different costs have different behavior.

Our estimates imply that the timing of work during the year is important. Working primarily during the summer improves academic capital accumulation, while working during the semesters is detrimental. We find significant earnings premiums of 17% for 2-3 year degrees and 27% for 4-5 year degrees, and each additional course credit also increases earnings by 1.5%.

Policy simulations show that an intermediate amount of means-testing on student income balances the incentives to work and accumulate academic capital as graduation rates and overall human capital is the highest when the means-testing is close to the pre-reform level. These policy responses are largest for those who acquire more academic capital, which means that income

[3] See e.g. Card and Hyslop (2005); Todd and Wolpin (2006); Heckman (2010); Keane et al. (2011); Attanasio et al. (2012); Blundell and Shephard (2012); Blundell et al. (2016).

inequality and overall discounted utility also is maximized at this intermediate level of means-testing. Changes in the grant share have little impact on dropout and graduation rates, but a large impact on student debt at exit. For example, doubling the grant share – such that 55% of total aid is a grant – increases debt at exit by 39% without altering human capital significantly. This means that the government can decide who bears the college cost without affecting human capital accumulation by changing the grant share.

Repayment plans that front-load debt repayment – by increasing income-contingency or shortening the loan repayment period – reduce student debt and allow the government to recuperate college costs earlier, but at the cost of slightly lower human capital accumulation during the college years as students finance more of the college cost by working and less by taking-up loans. Income-contingency of repayments exhibits an elasticity of -0.72 for debt and -0.14 for income at exit, but is marginally decreasing such that increasing the implicit tax rate on post-college income by 1 percentage point (from 4% to 5%) has just less than half the impact of increasing it by 6 percentage points (from 4% to 10%) which reduces debt at exit by 1.60% and income potential at exit by 0.35%. It is not surprising that students take up less debt when it becomes more costly, but students tend to compensate by working more such that they accumulate less academic capital and consequently have a lower income potential at college exit. These forces are weaker for dropouts than for college graduates, which implies that increasing income-contingency reduces income inequality; for example, increasing the implicit tax rate by 1 (6) percentage points – from a baseline level of 4% – reduces the P90/P10 income fraction by 0.26% (0.44%) from a baseline of 12. Further increases in income-contingency have little impact on outcomes because of the decreasing marginal responses as the implicit tax rate increases beyond 10%. Proponents of income-contingent repayment plans typically focus on the insurance aspect of it for those who get bad labor market draws after college exit, but our results suggest that their adverse effects on human capital accumulation should also be considered.

Overall, the policy instruments work on different margins, different subgroups of students, and have different distributional effects. The work margin tends to be more elastic as students react to changes in aid policies by changing how much they work during college, and less strongly by changing their student loan take-up. As a consequence, policies that directly affect work incentives (e.g. means-testing) are more effective in changing academic outcomes than those that affect budget sets through how loans are designed. The policy simulations show many asymmetries and non-linearities where increasing or decreasing the same policy instrument in isolation has very different effects on student choices and outcomes. Detecting and quantifying these differences would not be possible without detailed panel data and a carefully specified and estimated dynamic model.

We also find that interactions between policy instruments are important to consider. This suggests that existing estimates in the literature that only focus on one policy instrument and fail to account for alternative funding channels may be biased. For example, increasing the grant share when the repayment plan is income-contingent (annuity based) reduces (increases) income inequality. The reason is that the grant share affects academic capital more with income-contingent repayment plans. On the contrary, human capital investment are less sensitive to how heavily loans are subsidized (i.e. the interest rate) if repayment plans are income-contingent because of the differential human capital accumulation incentives by income potential.

Quantifying the impact of financial aid on human capital accumulation is important because a highly educated labor force is key to sustaining economic development, innovation, and growth. At the same time, the high levels of student debt are a core concern, as tuition and student debt have grown rapidly over the past five decades. Whether student debt is too high or perhaps not high enough to overcome capital market imperfections is still an open question.[4] This paper does not attempt to answer whether student debt is too high, but rather to understand the behavioral impact of student debt on human capital accumulation. These effects are first-order, but have been largely overlooked in the literature. By developing a framework that explains debt accumulation, education, and labor supply responses to incentives and their long-term effects for earnings capacity, we also contribute to the understanding of the broader impact of financial aid and its role in redistribution, insurance, and incentives. In this context, our model and empirical results are directly relevant for the design of optimal human capital policies that balance incentives and insurance.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the data. Section 4 describes the Swedish study aid system and the reform. Section 5 sets up the structural dynamic model and its estimation. Section 6 presents the results of the estimation and assesses model fit. Section 7 discusses various policy simulations based on the estimated model. Finally, section 8 concludes.

[4] Friedman (1962) first noted that student loans can improve economic efficiency by raising the supply of talented workers with a college degree and thus help overcome social underinvestment in human capital due to capital market imperfections; e.g. credit constraints, growth externalities, and static externalities to the extent that education improves health and the democratic process or lowers crime and unemployment rates.

## 2 Related Literature

Study aid policies change incentives to invest in human capital both in terms of education and labor market experience. We provide an empirical framework to analyze both the short- and long-term effects of study aid policies. Earlier studies have either focused only on short-term effects, only on long-term effects, on a subset of the budget set, or on a subset of the study aid policies we analyze in this paper. These are all important aspects, but studying them in isolation ignores crucial policy interactions and channels through which they affect outcomes.

There is a large (quasi-)experimental literature on the impact of grants on short-term outcomes such as college enrollment, performance during college, and persistence.[5] This literature has provided important evidence on how college costs can imped college access, but it does not focus on how grants (or college costs) affect behavior during college, human capital at college exit, and outcomes after college. The amount of grant funding available and to whom it is targeted affect the need to work and borrow – which determine future earnings capacity and the returns to college through opposing channels. Even if the estimates of the short-term impacts of grants are internally valid, they abstract from important interactions between grants and alternative funding channels *and* how these can lead to very different long-term effects.[6]

Although student loans are widespread and student debt has increased substantially over the last decade (Lochner and Monge-Naranjo, 2012; Avery and Turner, 2012; Brown et al., 2015), little is known about the impact of more generous loans on student performance.[7] A notable exception, Solis (2015) estimates the causal effect of loan access on college enrollment using Chilean data and a discontinuity in eligibility rules. He shows how loan access can close the socioeconomic gap in college enrollment, but abstracts from how the effect of loan access interacts with alternative funding opportunities; e.g. need-based grants. The demand for loans

[5] See e.g. Dynarski (2003); Bettinger (2004); Bound et al. (2007); Dynarski (2008); Goodman (2008); Angrist et al. (2009); DesJardins and McCall (2010); Scott-Clayton (2011); Garibaldi et al. (2012); Angrist et al. (2014); Barrow et al. (2014); Cohodes and Goodman (2014); Dearden et al. (2014); Angrist et al. (2015); Castleman and Long (2016).

[6] Two notable exceptions are Joensen (2013a) and Joensen (2013b) who incorporate how grants affect work choices during college and earnings after college. These papers do not include student loans in financial aid packages, thus abstract from the interactions between grant and loan financing and their different intertemporal trade-offs.

[7] According to OECD (2009), 75% of Swedish, 65% of Norwegian, 80% of UK, and 55% of US students in higher education have loans, while very few Danish and Finnish students have loans. This amounts to 61% of student aid in Sweden, 67% in Norway, and 58% in the US. Study aid amounts and coverage in Sweden are similar to those in other Nordic countries, although grant shares differ. Similarly, the UK government provides Maintenance grants and loans to cover living costs in addition to the aid covering tuition costs. The US Federal Government also offers students access to borrow (e.g. Stafford loans) up to the total cost of college – including tuition, room, board, books, and other expenses directly related to college – less any other financial aid received in the form of grants.

would be lower if grants were more generous. Like the rest of the (quasi-)experimental literature on the impact of aid on short-term outcomes, Solis (2015) also does not focus on how student loans affect college persistence, work choices during college, and outcomes after college.

Another strand of literature takes the stock of human capital and debt at college exit as exogenously given and estimates their long-term impact. Dearden et al. (2008) focus on how income-contingent loan repayments affect the distribution of earnings, Rothstein and Rouse (2011) show that high debt burdens decrease the likelihood of choosing low-paid careers (e.g. as teachers), and Luo and Mongey (2016) additionally document that more student debt implies lower job satisfaction and induces more on-the-job search. This literature overlooks that student loans affect behavior during college, such that education, labor market experience, and debt at exit are endogenously determined by the implicit incentives in financial aid packages.

We provide a unified framework for quantifying the impact of financial aid on both short- and longer-term outcomes. We build on a large literature on the specification and estimation of dynamic discrete choice models. We extend the model of Joensen (2013a,b) which incorporates student grants into a simplified version of the Eckstein and Wolpin (1999) model. Most importantly, we incorporate student loan take-up choices and endogenous student debt accumulation into the model. The paper most closely related to ours is Johnson (2013), which incorporates student loans into the Keane and Wolpin (2001) model by approximating the Federal Family Loan Program (FFEL) loan program rules in a dynamic model with private credit limits, tuition differences across states, and proxies of need- and merit-based grants. In the following we highlight a few aspect of the institutional setting and the data that make Sweden a better laboratory for quantifying the impacts of financial aid. First, we measure student budget sets much more accurately. It is not possible to get a good measure of actual student aid opportunities in the US due to the complexity and multiplicity of student aid programs as aid is provided by colleges, states, and at the federal level.[8] Furthermore, it is not possible to get a good measure of the actual college cost in the US – tuition minus grants offered by colleges – at the individual student level in data sources that can be linked to performance during college and labor market behavior.[9] Johnson (2013) uses self-reported data on the total amount of grants and loans from

[8] Kane (2006), Lochner and Monge-Naranjo (2011), Brown et al. (2012), Avery and Turner (2012), and Dynarski and Scott-Clayton (2013) provide a more detailed description of financial aid in the US. Brown et al. (2015) utilize the FRBNY Consumer Credit Panel to get measures of total student debt, but this data source does not distinguish between federal and private student debt which makes it impossible to know repayment plans. Furthermore, this data cannot be linked to individual level data on college and labor market choices and outcomes.

[9] Fillmore (2016) uses data from the Free Application for Federal Student Aid (FAFSA) to show that colleges

the NLSY97 to proxy that aid is a decreasing function of parental income because of need-based grants and loans (e.g. the Pell grant and Stafford loans) and an increasing function of student ability (measured by AFQT scores) because of merit-based aid. Johnson (2013) proxies tuition costs by average state tuition, setting state as an initial condition. Despite doing such a careful job with the available data, non-random and non-trivial measurement error may bias the estimated impact of aid availability as the actual college cost in the US is college-individual-specific and depends on stated student college preferences (Fillmore, 2016). Furthermore, even if FFEL program rules are approximated perfectly, this program only comprises around 35% of federal loans and eligibility interacts with other available aid programs. Second, the detailed data on student work, course credits, and degrees allows us to model the trade-offs in human capital investments in much more detail. Keane and Wolpin (2001) and Johnson (2013) allow student income to be a source of consumption, but not to directly affect college achievement. We show this is a significant channel when evaluating study aid policies. Ignoring the direct impact of student work hours on academic achievement biases estimates of the effects of student aid on outcomes as these are correlated with college-work choices. Finally, Keane and Wolpin (2001) and Johnson (2013) only model degree completion and only estimate degree premiums. We model academic skill acquisition at the course credit level – including the self-productivity of skills (Cunha and Heckman, 2007) – as we have detailed data on accumulated course credits each semester. Acquired degrees are conditional on accumulated course credits. We estimate degree premiums *and* how much course credits increase earnings capacity. We thus allow college dropouts to have different earnings capacity depending on how many credits they have accumulated. For example, this allows college dropout Steve Jobs to increase his earnings capacity by taking a calligraphy class.[10] This is also an important margin, as it allows us to assess achievement much more accurately and estimate how close students are to degree completion. A significant contribution is thus that we can both model students' college progression and actual funding opportunities much more accurately as well as relating them to longer term labor market outcomes.

The 2001 reform of the Swedish study aid scheme provides us with exogenous variation in budget sets. Avdic and Gartell (2015) analyze the impact of this reform on a measure of

price discriminate such that the actual college cost – sticker tuition fee minus college discounts through grants – is lower for individuals with higher ability and lower parental income.

[10] According to his Stanford commencement address in 2005 it was a calligraphy class he took at Reed College that gave him the inspiration for the MAC typography.

study efficiency. They find that the reform results in low socioeconomic status students working more and consequently slowing down their academic achievement relative to high socioeconomic status students. They estimate short-term ex-post total effects of the reform, and hence are not able to separate out its various components; e.g. different loan repayment plans, increased grant share, and more generous means testing. Furthermore, they do not account for student loan decisions and dynamic selection; i.e. the fact that it is not random who is still enrolled in college at any given point in time. They are thus not able to disentangle the impact of the various policy instruments changed by the reform, the mechanisms by which they affect study efficiency, or how these affect long-term outcomes through earnings capacity. These are all crucial components to enable ex-ante policy evaluation. We build the complete study aid rules into our dynamic model and use the quasi-experimental variation provided by the reform to estimate key model parameters. The idea of combining a quasi-experiment with a structural dynamic model has been strongly advocated (Card and Hyslop, 2005; Todd and Wolpin, 2006; Heckman, 2010; Keane et al., 2011; Attanasio et al., 2012; Blundell and Shephard, 2012; Blundell et al., 2016), but has not previously been implemented in an analysis of the effects of student loans.

Finally, our paper also contributes to the literature on borrowing constraints.[11] This literature finds that despite the tightness of borrowing constraints, removing them has a negligible impact on education attainment and achievement. This is found both for the US (Keane and Wolpin, 2001; Carneiro and Heckman, 2002; Cameron and Taber, 2004; Johnson, 2013) and for Denmark (Nielsen et al., 2010). Recently, some papers have questioned this result. Lochner and Monge-Naranjo (2011) underline the increasing importance of credit constraints for recent cohorts in the US, with increasing tuition fees and an increasing share of students borrowing the maximum student loan amounts.[12] These papers make significant contributions to our understanding of the nature and importance of borrowing constraints. However, none of these papers allow students to self-finance consumption during college by working, which is an important source of income and a potential source of bias in assessing the importance of borrowing constraints. Ignoring students' ability to self-finance their studies by working overestimates the opportunity cost of college. This introduces a systematic bias in the opportunity cost of college, since it is not random which students work and how much they work.[13]

[11] Lochner and Monge-Naranjo (2012) provide a recent comprehensive survey of this literature.

[12] Brown et al. (2012) and Mattana (2013) also stress the importance of strategic interactions in the family to understand the real impact of credit constraints on education outcomes.

[13] Students self-finance a considerable amount of their college costs through working part-time while enrolled

# 3 Data

We use register-based individual panel data of the Swedish population hosted by the Institute for Evaluation of Labour Market and Education Policy (IFAU). Our enrollment sample contains all high school graduates who enroll in a university program or course between 1994 and 2002 and are younger than 23 years old by the end of their initial enrollment year. This amounts to 228,262 individuals. To conduct out-of-sample model fit, we add 70,420 students enrolled in 2003 and 2004. To account for the initial enrollment choice, we also include all high school graduates from the 1994-2002 cohorts who are not older than 20 when graduating from high school and have not enrolled in college by the time they are 23 years old. In total, our sample includes 769,215 individuals and a total of 9,211,472 yearly observations on their education and labor market choices and outcomes until 2009.

We have complete education event histories for this population, including high school GPA and track as well as university spells for those who enroll in higher education. For every university enrollment spell we observe the duration, level and field of study, and acquired course credits (ECTS) every semester in every course they take. We also have study aid accumulated each year. Labor market histories include official employment status, employment spells with spell-specific earnings, and total yearly earnings. Finally, we observe a range of demographic characteristics and background variables, including parental characteristics such as parental yearly income, field and level of education, employment and civil status. Detailed information about the variables and sample selection can be found in Appendix A.

Descriptives are shown in Table 1, descriptives showing additional dimensions of heterogeneity, including gender, field of study, and parental characteristics, can be found in Table 8 in Appendix D. Individuals enrolled in a university program complete one year when they produce 60 ECTS. Programs can require a minimum of 2 years, or 120 ECTS credits, 180 ECTS are necessary for acquiring a 3-year degree, 240 for a 4-year degree, and 300 for a 5-year degree. Students choose the length of the program at enrollment – since 2-year and 5-year programs are not common, we group the 2 and 3-year programs as well as the 4 and 5-year programs together. Individuals are around 20 years old at initial college enrollment and 55% are females. On average, students enroll in college one year after graduating from high school, and

in college: Leslie (1984) reports that US students self-finance around 20% of college expenses. Bound et al. (2007) show that student employment has increased over time and speculate that this reflects students self-financing increased tuition fees.

Table 1: Descriptives

| Individual Characteristics | No College | Enrolled | Dropouts | Graduates 2-3 years | Graduates 4-5+ years |
|---|---|---|---|---|---|
| **At University Entry** | | | | | |
| Age | | 20.16 (1.02) | 20.26 (1.05) | 20.22 (1.03) | 19.97 (0.94) |
| Age at high school graduation | 19.02 (0.50) | 19.06 (0.41) | 19.07 (0.44) | 19.04 (0.39) | 19.07 (0.37) |
| Work Experience (years) | 2.42 (1.12) | 2.19 (1.26) | 2.20 (1.30) | 2.36 (1.27) | 2.03 (1.19) |
| High school GPA ($\geq P75$) | 0.09 | 0.45 | 0.33 | 0.40 | 0.67 |
| High school GPA ($\geq P90$) | 0.02 | 0.20 | 0.12 | 0.13 | 0.37 |
| High school GPA | 2.75 (0.62) | 3.35 (0.59) | 3.20 (0.58) | 3.31 (0.55) | 3.61 (0.53) |
| High school math-science track | 0.05 | 0.32 | 0.26 | 0.24 | 0.49 |
| **During enrollment** | | | | | |
| Employed (only summer) | | 0.44 | 0.41 | 0.42 | 0.47 |
| Employed (academic year) | | 0.41 | 0.40 | 0.45 | 0.37 |
| Course Credits (per year) | | 33.96 (27.25) | 27.00 (24.47) | 35.31 (27.57) | 39.26 (28.05) |
| Loan (per year) | | 22,643 (20,980) | 21,588 (20,536) | 21,718 (20,509) | 24,349 (21,632) |
| **At University Exit** | | | | | |
| Total Course Credits | | 200.26 (110.66) | 124.85 (101,67) | 217.72 (64,27) | 292.64 (76.72) |
| Debt | | 133,172 (95,378) | 100,460 (90,439) | 132,699 (81,841) | 181,142 (94,492) |
| Work Experience (years) | | 5.32 (2.53) | 4.48 (2.49) | 5.87 (2.40) | 6.00 (2.36) |
| **After University Exit** | | | | | |
| Employed | 0.87 | 0.92 | 0.88 | 0.96 | 0.95 |
| Yearly Earnings | 132,347 (101,321) | 223,590 (136,626) | 197,200 (132,638) | 221,296 (114,898) | 283,286 (150,561) |
| **N individuals** | 410,578 | 287,649 | 120,122 | 81,983 | 85,589 |
| **Fraction of Sample** | 0.59 | 0.41 | 0.17 | 0.12 | 0.12 |
| **Fraction of Students** | | | 0.42 | 0.28 | 0.30 |

Sample averages, standard deviations in parenthesis. One year of full-time studies corresponds to 60 ECTS. All amounts are in real SEK 2000. The exchange rate ultimo December 2000 was 9.3955 SEK/USD and 8.8263 SEK/EUR.

have also accumulated work experience during high school. The college dropout rate is 42%, and of the rest of the students, 28% graduate with 2-3 year degrees and 30% with 4-5+ year degrees. Approximately half of the dropouts and the 4-5+ year graduates are female, while more females than males get a short college degree: 67% of all 2-3+ year graduates are female. High school graduates enrolling in college have a higher than average GPA of 3.35 (on a 1-5 scale), 45% of them are in the top quartile, and 20% of them are in the top decile of their respective high school cohorts. 32% of college students at university entry have graduated from the math-science high school track, as opposed to only 5% of those not enrolling in college. In our model and estimation, we use an indicator for being in the top decile of the high school cohort as a measure of ability, and an indicator for having graduated from the math-science high school track as a measure of skill. Dropouts and those with a short degree are not substantially different on observables, but those with a long degree are positively selected on GPA and math-science high school track. A large fraction (85%) of students are employed: 41% work during the academic year and 44% work only during the summer months. Students accumulate around half of mandated course credits each enrollment year, and those eventually acquiring a longer college degree also tend to be more productive at accumulating course credits in each enrollment year. Dropouts only produce 27 ECTS on average per enrollment year, while those graduating with a shorter (longer) degree produce 35 (39) ECTS. Students tend to accumulate more than the required course credits at university exit. This could reflect switching between fields, a high consumption value of university attendance, or simply a high return to course taking. Those with longer degrees also accumulate more student debt, have a higher income, and a higher employment probability after university exit.

## 4 The Swedish Study Aid System

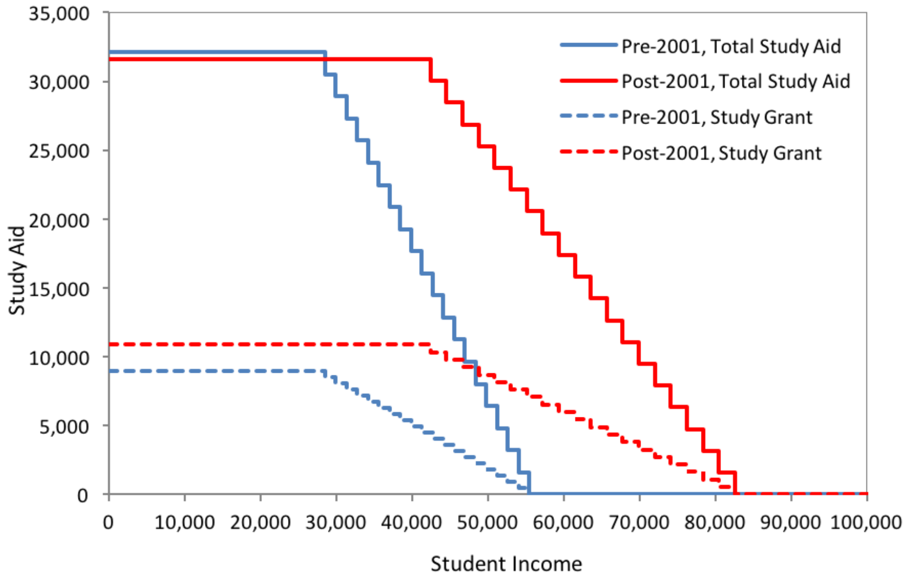
Sweden is one of the European countries with the highest share of college graduates *and* with one of the highest expenditures per student.[14] Higher education is tuition-free for all students and largely financed by the central government. Moreover, 26% of the sizable total public expenditure on higher education is targeted to grants and loans for students. The Swedish study aid program has been in place since 1919. Student aid is universal and administered by the central study aid authority: Centrala Studiestödsnämnden (CSN). Applying for the aid is fast and simple – the rules are uniform, transparent, and have not been fundamentally changed since 1965.[15]

Upon enrollment in higher education, all students are eligible for study aid up to a maximum of 240 weeks, i.e. 12 semesters. In 2001, maximum weekly aid was 1,605 SEK, which amounts to 64,232 SEK per year. Eligibility from the second year onwards depends on merit: students are required to complete 75% of the required course credits in order to maintain eligibility for the following year. Every semester, the amount of aid available is means tested on the student's income: all income earned above a threshold amount reduces the available aid proportionally

[14] The annual public expenditure per student in tertiary education is about 14,000 EUR per year - almost double the EU average of 8,000 EUR per year (Eurostat, 2009)

[15] This means that informational barriers should be minimal and much less important than in other settings (Bettinger et al., 2012; Booij et al., 2012; Hoxby et al., 2013).

Figure 1: Maximum Study Aid and Grant as a function of Student Income.




The Figure displays the maximum student aid and grant amount as a function of student income. All amounts are per semester in real SEK 2000. The exchange rate on December 31, was 9.3955 SEK/USD and 8.8263 SEK/EUR.

until it reaches zero. The total aid amount is accessible to the student in part as a grant – not requiring repayment – and in part as a subsidized loan to be repaid after exiting university. Eligible students can decide whether to receive only the grant or to also take up the loan. Specifically, students can decide how many weeks of loan to receive each semester – up to a maximum of 20 weeks per semester for full-time students.

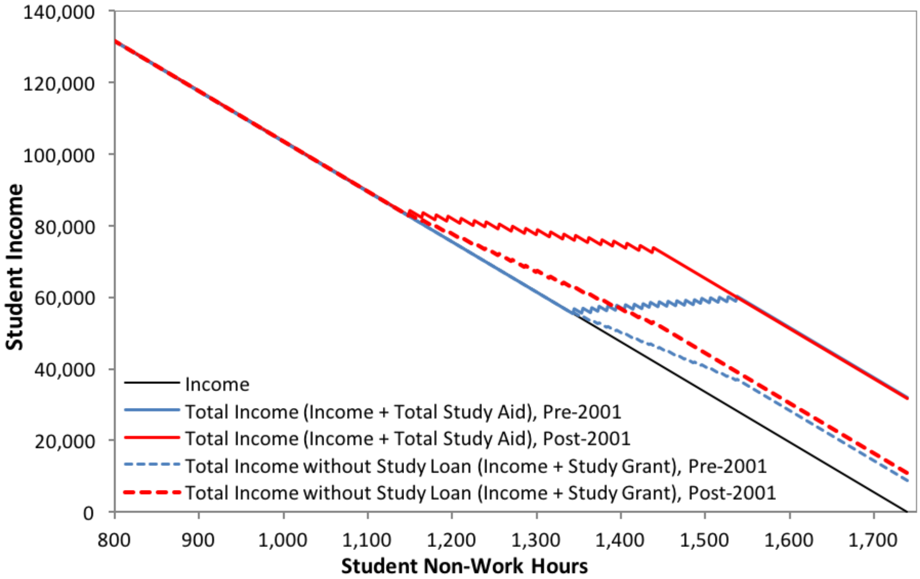
The following two subsections, present the details of the 2001 reform of the Swedish study aid rules. First, we discuss how each policy parameter shocked by the reform affects different margins of choice in the model we specify and estimate in Section 4. Second, we show the total reform impact on student budget sets, work-loan choices, income, and debt in order to highlight the exogenous variation in the data.

## 4.1 The 2001 Reform

In 2001 a comprehensive reform affected four major aspects of the study aid scheme: means testing and income requirements, the grant share, time and merit requirements, and the loan repayment plan. These aspects of change are detailed in the following four subsections.[16]

[16]See CSNFS (2001) for even more details on the reform.

Figure 2: Total Student Income, Before and After the Reform




The Figure displays total student income - including the maximum student aid and grant amount - as a function of student leisure hours; i.e. yearly hours not worked. The Figure is constructed assuming a non-working student has 1739 leisure hours a year and working students have an hourly wage of 140 SEK. All amounts are per semester in real SEK 2000. The exchange rate on December 31, 2000 was 9.3955 SEK/USD and 8.8263 SEK/EUR.

#### 4.1.1 Student Income Thresholds and Means Testing

Students are means tested on a half-year basis. Students receive the maximum aid amount if their income is lower than the *maximum income threshold*, $\overline{Y}$. If student income is above the threshold, the aid amount the student is eligible for decreases proportionally at rate $\tau$ as income increases. As illustrated in Figure 1, the threshold increased from $\overline{Y}_{pre} = 27,675$ SEK in the spring semester of 2001 to $\overline{Y}_{post} = 46,125$ SEK in the fall semester. The threshold is calculated every year as a proportion of an inflation adjusted base amount, *prisbasbelopp*, and it went from a yearly average of 0.75 (0.65 in the spring semester and 0.85 in the fall semester) before the reform to 1.25 after the reform.[17] In practice, the aid amount decreases proportionally in discrete steps of weekly aid until the student is no longer eligible for any aid. This means that students earning more than 55,350 SEK (92,250 SEK) per semester during the last (first) semester before (after) the reform would not receive any aid. This is equivalent to a reduction of the labor income tax: the total income of students, composed of aid and labor income, is taxed less after the reform as the implicit tax on total student income above the threshold went from $\tau_{pre} = 1.189$ to $\tau_{post} = .786$.

[17] Further details about the *prisbasbelopp* for the relevant years are in Appendix A.2.

The immediate impact of the income threshold increase is that more students are eligible for the maximum aid amount; thus, fewer students face the implicit tax rate. The decrease in the tax rate further lowers work disincentives. Figure 2 illustrates the budget constraint of the students, with total income (consumption) on the Y-axis and non-work hours (leisure) on the X-axis. The budget sets clarify the potential labor supply effects of the change in the means testing rules. There is no effect on the extensive margin of labor supply and no effect on students earning less than the pre-reform threshold. A student working many hours, who was far from being eligible for aid before the reform, may now work fewer hours and receive the same utility. Students working an intermediate amount of hours may either work more to take advantage of the lower tax rate, or work less and receive at least as much income. The overall effect of the means testing on the intensive margin is thus an empirical question as it depends on the relative strengths of the income and substitution effects on student labor supply.

#### 4.1.2 Grant and Loan Proportions

With the reform, the total amount of aid available to every student was left unchanged, but the grant share was made more generous: from 27.8% to 34.5% of total aid.

The increase in the grant share directly loosens the student budget constraint. Fewer students may take up the loan if the higher grant amount provides sufficient credit. This increase may also affect student labor supply, as illustrated in Figure 2. A student working $h$ hours could get a higher total income post-reform or the same total income as before, but with fewer hours worked. Depending on income and substitution effects, students may simply work the same amount of hours at a higher total income or work less at the same income. Hence, the increased grant share affects both the intensive *and* the extensive margin of student labor supply.

#### 4.1.3 Time and Merit Eligibility Requirements

Eligibility requirements were also changed along various dimensions. First, part-time enrollment choices were expanded to include 75% of full-time studies, compared to only 50% before the reform. Second, the merit requirements for the first year of higher education were relaxed from 75% to 62.5% of the ECTS enrolled for at the beginning of the year. We do not model the part-time enrollment choice since, from the data, it appears that very few students enroll part-time. Finally, it became easier to regain eligibility after losing it for one or more semesters. According to CSN (2002), students were informally able to receive aid longer than the 12 semesters of stated eligibility (up to 14-15 semesters) before the reform, but this rule was enforced more strictly after the reform.

The lower merit eligibility requirement, in terms of course credits produced the period before, affects the trade-off between studying and working. To the extent that student work-hours have a detrimental (beneficial) effect on course credit production, the lower merit requirements may increase (decrease) student labor supply.

#### 4.1.4 Loan Repayment Plans

The loan repayment plan was changed from an income-contingent plan (*studielån*) to an annuity-based one (*annuitetslån*). Before the reform, the installments consisted of 4% of the labor income earned 2 years earlier (with a minimum installment of 1,320 SEK). The debt was written off in case of (a) turning 65 years old, (b) death, (c) sickness.

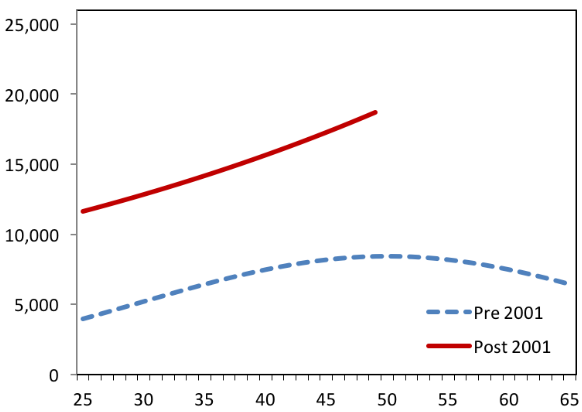
After the reform, the installments became a 25 years annuity calculated according to the following formula:

$$\widehat{a}_t = D_{t-1} \times (r - p) \times \frac{\left(\frac{1+r}{1+p}\right)^{25}}{\left(\frac{1+r}{1+p}\right)^{25} - 1} \times (1 + p)^{(t-1)}. \tag{1}$$

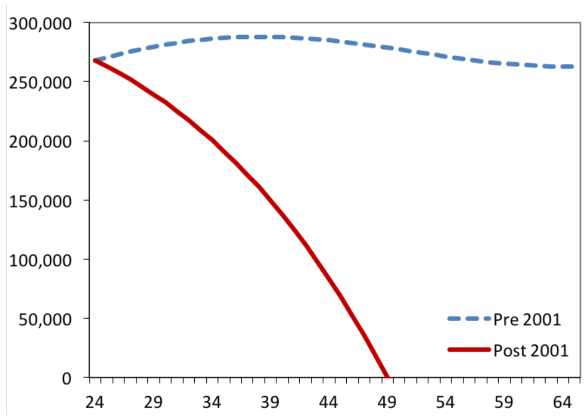
where $D_{t-1}$ is cumulated student debt, $p = 2\%$ is an increment of the annuity to mimic wage growth, and $r$ is the interest rate. The interest rate is set by the government to be 70% of the average cost of government borrowing over the past three years. A flavor of income contingency was kept as it is possible to apply twice for a reduced installment. The requirements for the reduced installment are either a negative income shock or receiving unemployment or disability benefits. The reduced installment consists of 5% of current income - after which the 25 years annuity repayment plan is recalculated. The debt is written off in case of (a) turning 68 years old, (b) death, (c) sickness.

The loan repayment plan directly affects the expected future value of working, since the repayment depends on the level of student debt, on future income (before the reform), and consequently on current loan take-up decisions. The reform meant that this intertemporal trade-off became stronger for low earners and weaker for high earners. Figure 3 illustrates the expected repayment plans under the two regimes for a simulated student with the maximum possible pre-2001 student debt and different labor market entry income. The figure shows that the reform meant higher installments for the low earner and lower installments for the high

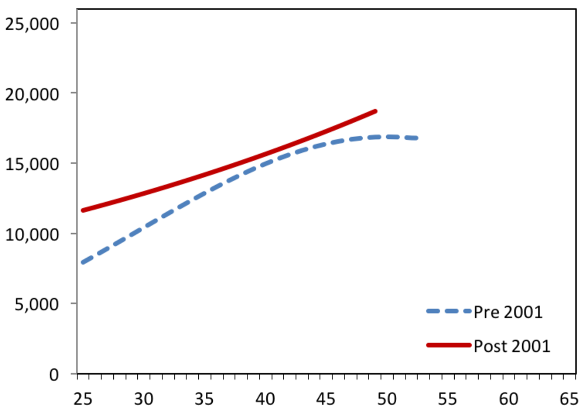
Figure 3: Expected repayment plan and Evolution of Debt.



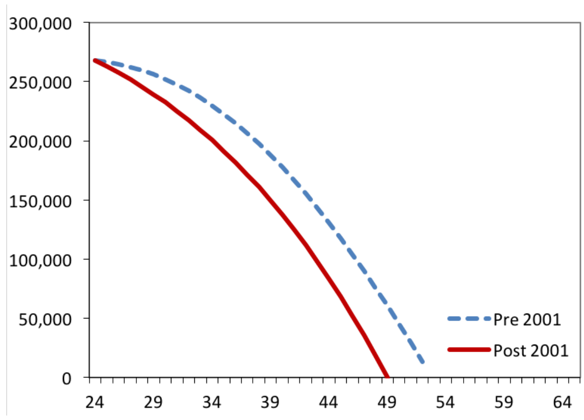

(a) Expected Repayment, starting salary SEK 99,426



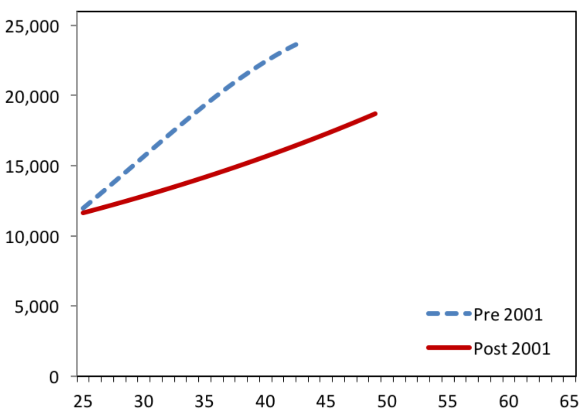

(b) Evolution of Debt, starting salary SEK 99,426



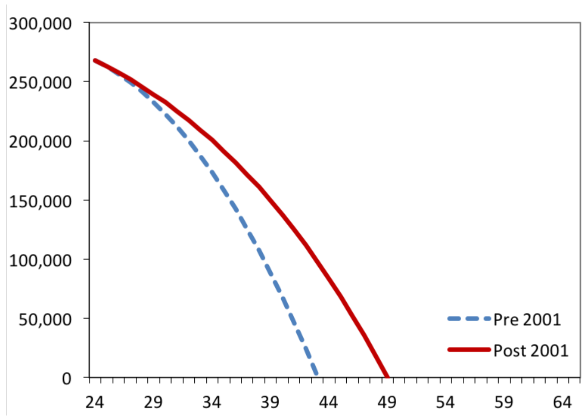

(c) Expected Repayment, starting salary SEK 198,981




(d) Evolution of Debt, starting salary SEK 198,981




(e) Expected Repayment, starting salary SEK 298,536




(f) Evolution of Debt, starting salary SEK 298,536

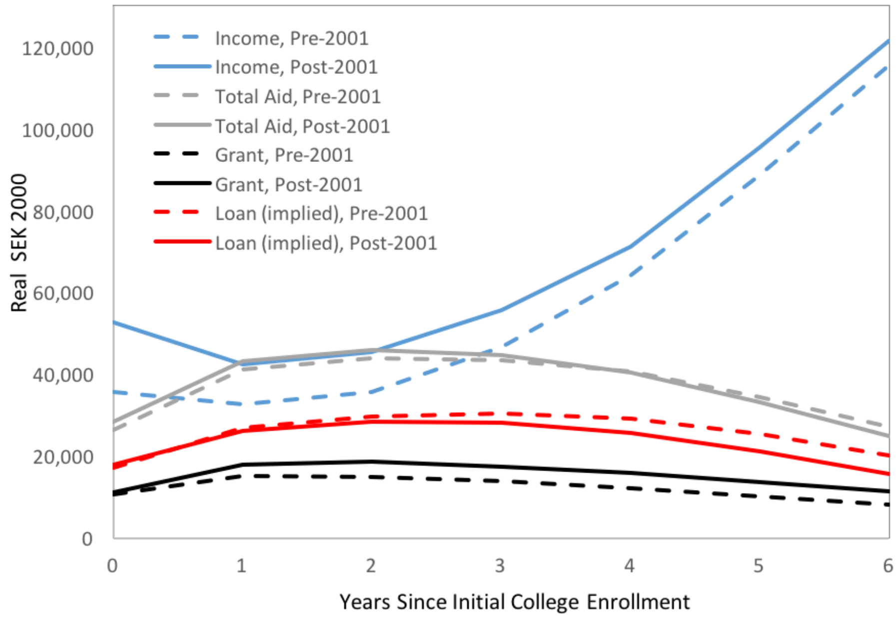
This Figure displays the expected repayment plan and evolution of debt for a full-time student who exits college with 240 weeks of outstanding student debt (2001 amounts), and with starting yearly income equal to: (a) (b) the average in our sample minus one standard deviation (SEK 99,426), (c) (d) the average in our sample (SEK 198,981), and (e) (f) the average in our sample plus one standard deviation (SEK 298,536).
The income equation is assumed to be $\ln(Y) = \ln(Y_0) + 0.06H_t - 0.0012H_t^2$, where $Y$ denotes income and $H$ experience, and time $t$ starts at $t = 0$ when the student exits college. The interest rate on the loan is set at 2.5%. We assume that the student exits university and enters full-time work at age 24. Before the reform any remaining debt was forgiven at age 65. Pre-reform figures are displayed with dashed lines and post reform figures with solid lines. All amounts are in real SEK 2000. The exchange rate on December 31, 2000 was 9.3955 SEK/USD and 8.8263 SEK/EUR.

earner relative to before the reform. For an entry income of 198,981 SEK per month – the average income in our data and slightly higher than the average entry income of a college dropout – the two regimes are not very different: the yearly installments are slightly higher and the student fully repays the debt five years earlier after the reform. We calculate the present value of lifetime income as the present value of the repayment installments due by the student from when she starts repaying to when the debt is fully repaid, or alternatively, to when she reaches age 65. We find that the cost of the reform for the average earner is 10,924 SEK. For a starting income equal to the average minus one standard deviation, however, the pre-reform repayment plan consisted of much lower installments such that the student debt would never be repaid, as shown in Figure 3 (a) and (b). The present value of lifetime income of this low earner was reduced by 91,552 SEK. The opposite is true for a starting income equal to the average plus one standard deviation. This student repaid the debt faster in the pre-reform regime. The present value increased by 11,641 SEK for this high earner. The reform thus changes the incentives for human capital accumulation and debt accumulation in opposite directions for individuals with high and low earnings capacity.

## 4.2 Immediate Impact of the 2001 Reform

Did the reform actually have an impact on student choices and outcomes? In this section, we investigate the variation in choices and outcomes generated by the reform. Figure 4 displays the components of the budget set (student income, total aid, grant, and loan amounts) before and after the reform by years since initial college enrollment. The figure shows that student income increases significantly for all enrollment years. In accordance with the study aid scheme, the total aid stays roughly constant while the grant amount increased and the loan amount decreased. Students thus tend to finance more of their college education through working and borrow less after the reform. In Figure 5 we take a closer look at the income distribution of students before and after the reform. Figure (a) shows the income distribution: the vertical red lines are the thresholds for the means-testing before (dashed line) and after (solid line) the reform. The aid starts getting taxed after the first threshold, and the student becomes ineligible for aid after the second threshold. Figure (b) shows how the mass of students is distributed between thresholds. While there is no clear bunching around the thresholds, we see how the income distribution clearly moves to the right after the reform: the fraction of students that would be taxed before the reform, but who would still receive the full aid amount after the

Figure 4: Immediate Impact of Reform on Student Income and Aid




The Figure displays student income, total aid, grant, and loan amounts before and after the 2001 reform. All amounts are in real SEK 2000 and displayed separately by years since initial college enrollment (on the x-axis). The exchange rate on December 31, 2000 was 9.3955 SEK/USD and 8.8263 SEK/EUR. Figure 19 in Appendix C reports the reduced form estimates of the impact of the reform on each of these budget set components.

reform increases by 4.6 percentage point.

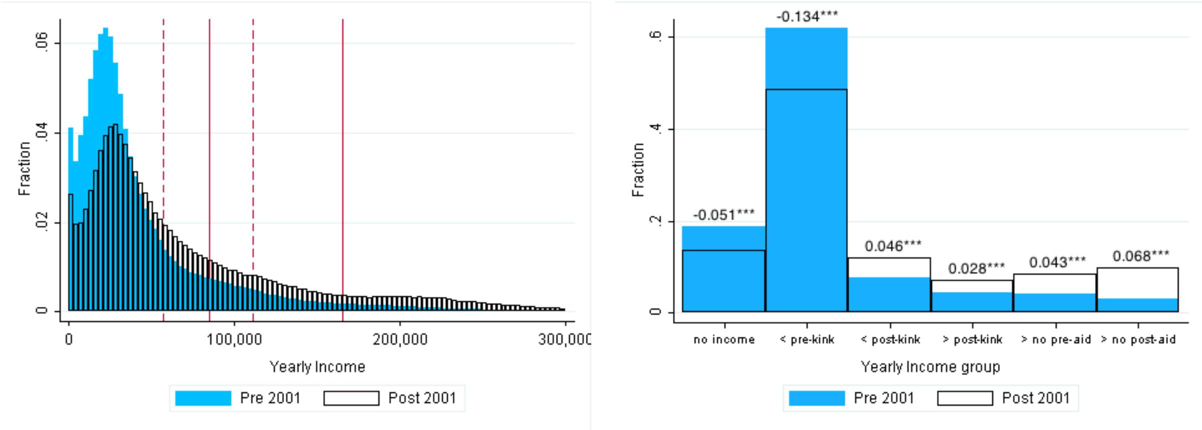
Figure 6 displays student choices: employment and loan take-up rates. It shows that more students work after the reform and more students take up the loan. Student employment, in particular, largely increases during the first college years, while loan take-up increases the most during the first college years and decreases thereafter. This suggests that more students take up some loan, but the average amount they take up is still lower because of the higher grant share.

Figure 7 shows how students are distributed over the work choices we model in the next section: not working, working only during the summer, and also working during the academic year. The increase in employment is confirmed both at the extensive and the intensive margin – the reform reduced the likelihood of not working by 5 percentage points and increased the likelihood of year-round work by 14 percentage points.[18]

In the next section, we also model student loan take-up choices: taking up only the grant and no loan, taking up half of the available loan, or taking up the full available loan. Figures 8 (b), (d), and (f) show the heterogeneous reform effects on loan take-up by expected income.

[18]When controlling for to the variables we include as initial conditions these estimates are lower (-0.02 and 0.04) but still statistically significant at any conventional level.

Figure 5: Before and After the Reform: Student Income

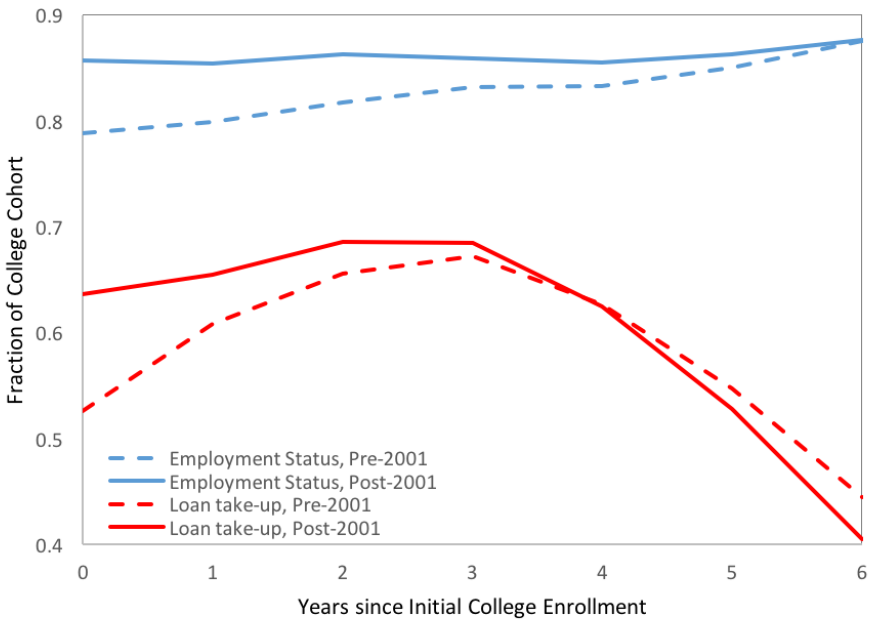



(a) Income Distribution

(b) Income Thresholds

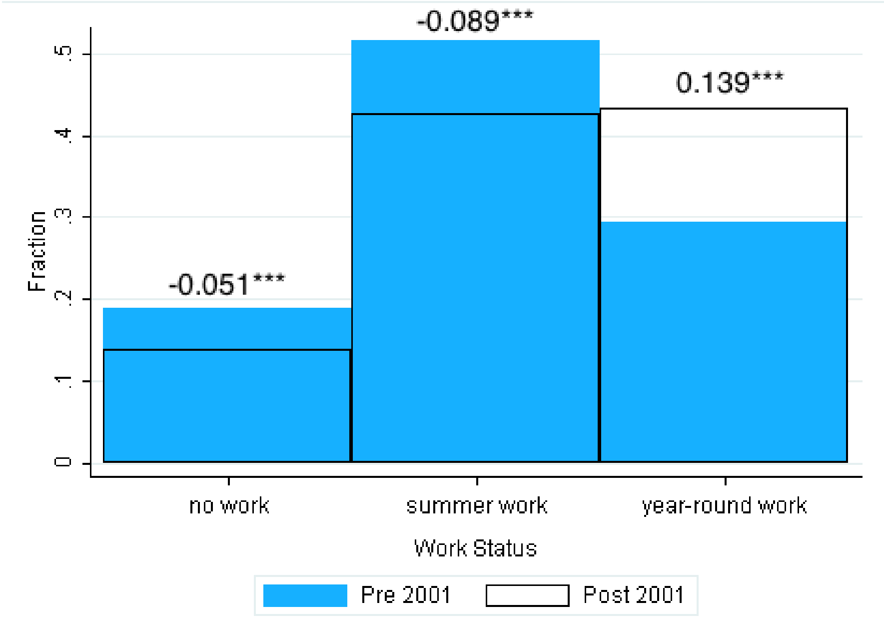
The Figure displays student income before and after the reform for both the spring and the fall semesters. Figure (a) shows the income distribution (in bins of 3,000 SEK). The vertical red lines cross at the income thresholds for the means-testing. The pre-reform thresholds are displayed with dashed lines and the post-reform thresholds with solid lines. Figure (b) shows how the mass of the distribution is allocated between thresholds. The numbers above the histogram are the coefficients from a before-after regression with no additional controls. The estimates are robust to adding year controls. *** denotes significance at the 1% level.

Figure 6: Immediate Impact of Reform on Student Employment Status and Loan Take-up




The Figure displays student employment and loan take-up choices before and after the 2001 reform. All numbers are displayed separately by year since initial college enrollment (on the x-axis). Figure 20 in Appendix C reports the reduced form estimates of the impact of the reform on each of these choices.

Figure 7: Before and After the Reform: Student Work Status




The Figure displays the work status of students before and after the reform. Students choose between not working, working only during the summer, or working year-round; i.e. also during the academic year. The numbers above the histogram are the coefficients from a before-after regression with no additional controls. The estimates are robust to adding year controls. *** denotes significance at the 1% level.

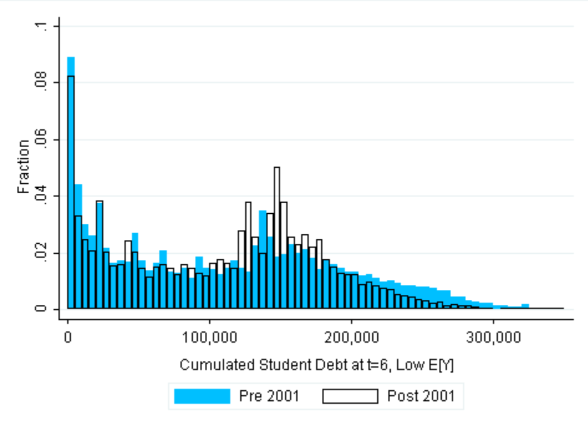
Expected income, denoted by $\mathbb{E}[Y]$, is calculated as the predicted income from a fully saturated regression of log-income on high school GPA and Math-Science track, labor market experience at college enrollment, level and field of enrollment. We see that those with low expected incomes become less likely to take up the loan. The increase in full loan take-up also tends to be higher for those with high expected income. The fraction of low $\mathbb{E}[Y]$ students who do not take any loan increases by 2 percentage points, while there is no impact on the extensive loan-take up margin for high $\mathbb{E}[Y]$ students.[19] This shift is as expected from the illustration in Figure 3 that shows how low expected earners have a higher borrowing cost after the reform, while high expected earners have a lower borrowing cost. Figures 8 (a), (c), and (e) display the distribution of student debt six years after college enrollment. High $\mathbb{E}[Y]$ students graduate with more debt than median or low $\mathbb{E}[Y]$ students both before and after the reform, but the reform only significantly increased average debt for high expected earners. Overall, the distribution of debt got more compressed as its standard deviation reduced by around 10,000 and the Gini Index reduced by around 0.05. This shift can be due to multiple factors; e.g. the increased

[19]When controlling for to the variables we include as initial conditions these differential responses are even stronger.

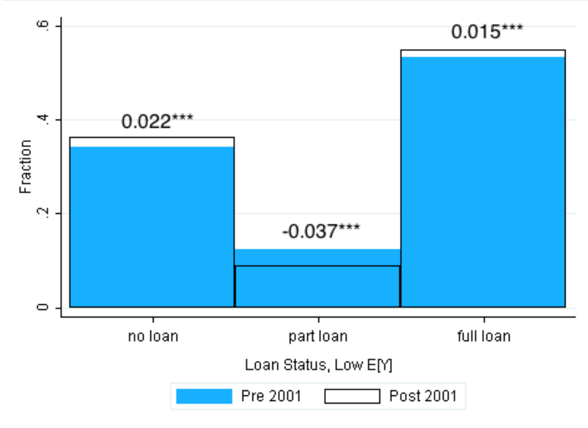
grant share, which means that student debt would decrease even if loan take-up choices were unaffected by the reform. The model we specify and estimate in the following sections will be able to disentangle these factors.

Overall, the major reform of the study aid scheme increased student employment and income, while it compressed the student debt distribution and caused high (low) expected earners to become more (less) likely to take up the student loan. Looking at the student budget set during enrollment, a higher fraction of college costs becomes financed by student income and grants while a lower fraction becomes financed by debt – this shift is largest for low expected earners. This is the exogenous variation in the data we exploit in order to identify and estimate our model parameters. We now turn to describing the model that we use to quantify and disentangle the mechanisms through which the various aid policy instruments affect student choices and outcomes.

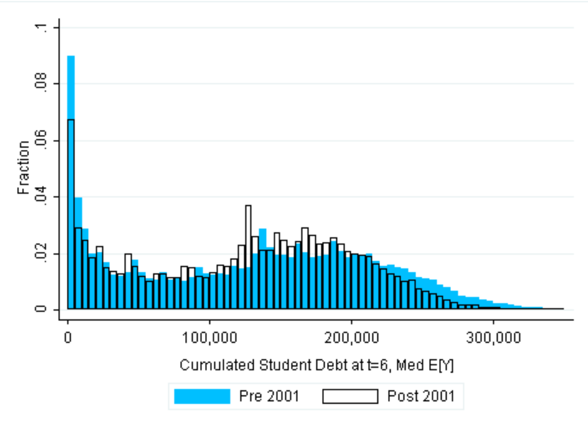
Figure 8: Before and After the Reform: Student Debt and Loan Status



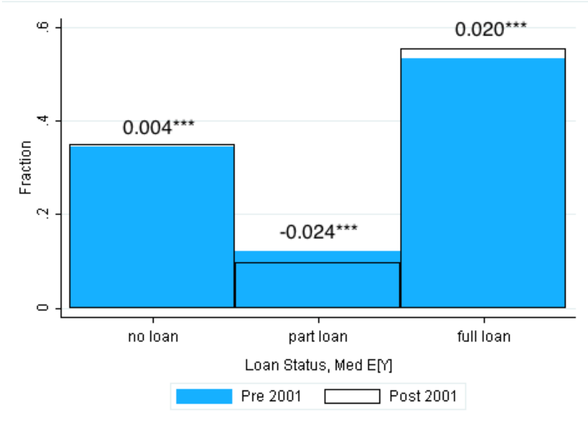

(a) Student Debt at $t = 6$, Low $\mathbb{E}[Y]$



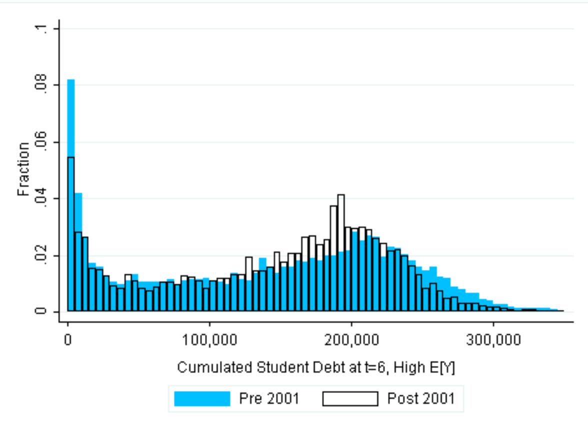

(b) Loan Status during enrollment, Low $\mathbb{E}[Y]$



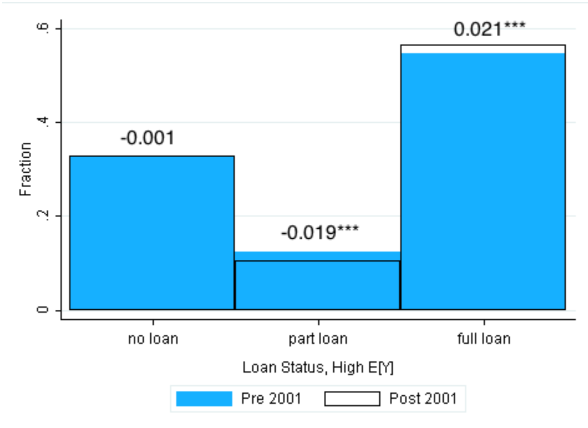

(c) Student Debt at $t = 6$, Med $\mathbb{E}[Y]$




(d) Loan Status during enrollment, Med $\mathbb{E}[Y]$




(e) Student Debt at $t = 6$, High $\mathbb{E}[Y]$




(f) Loan Status during enrollment, High $\mathbb{E}[Y]$

The Figure displays cumulated student debt and loan status before and after the reform. All figures are displayed separately by whether expected income is more than one standard deviation below the average (Low $\mathbb{E}[Y]$), more than one standard deviation above the average (High $\mathbb{E}[Y]$), or in between (Med $\mathbb{E}[Y]$). Expected incomes are based on the predicted values from a regression of log-income on a fully saturated model of initial conditions: an indicator for whether the student was in the top 10% of the high school cohort GPA distribution, an indicator for whether the student graduated from the math and science high school track, labor market experience at college enrollment, level and field of initial enrollment. The figures on the left side show the change in the distribution of student debt at $t = 6$ (in bins of 5000 SEK). The figures on the right show the changes in loan status during enrollment for $0 \leq t \leq 6$. The numbers above the histogram are the coefficients from a before-after regression with no additional controls. The estimates are robust to adding year controls. *** denotes significance at the 1% level.

# 5 The Model

In this section we set up the dynamic discrete choice model of joint education, work, and student loan take-up decisions. Choices are made at the individual level, but we suppress individual subscripts for most of this section for ease of exposition.

## 5.1 Individual choices

At $t = 0$, individuals are characterized by initial abilities and skills $A$ and $K$, labor market experience $H_0$, and type $m$. Initial abilities $A$ are measured by whether the student was in the top 10% of the high school cohort GPA distribution. Initial skills $K$ are proxied by whether the student completed the math-science track in high school. Initial experience $H_0$ captures the fact, documented in Section 3, that on average Swedish students delay college enrollment. Individuals exit high school with different characteristics that make it unlikely for them to have the same preferences for education, unobserved academic abilities with respect to course credit production, and labor market productivity beyond what is captured by observable characteristics $A$, $K$, and $H_0$. To account for this unobserved heterogeneity, we introduce an additional state $m$ that is unobserved, persistent over time, and whose distribution is correlated with the observed initial heterogeneity.

We model choices from time of initial college enrollment to exit, and $t$ denotes time since initial college enrollment. At $t = 0$, individuals decide whether to enroll in college, and if so, the length of the program: either 2-3 years or 4-5 years, $S_0 \in \{0, 3, 4\}$. After this initial choice, the model is an optimal stopping problem with finite horizon. From $t = 1$ onwards, students can decide to exit university and cannot re-enter. re-enter. By $t = 11$, everyone is out of college and in the labor force. Hence, every period after enrollment, students have to choose whether to continue with university studies, $s_t \in \{0, 1\}$, whether and how much to work while studying, $h_t \in \{0, \frac{1}{2}, 1\}$, and how much student loan to take up, $\ell_t \in \{0, \frac{1}{2}, 1\}$. These choices determine next period's cumulated course credits $G_t$, highest acquired degree $E_t$, cumulated student debt $D_t$, and labor market experience $H_t$. We also keep track of last period's choices of work and student loan take-up, denoted by $h_{t-1}$ and $\ell_{t-1}$. When not in college, either as never enrolled, dropouts or graduates, individuals work full-time for a wage that depends on their cumulated course credits, highest acquired degree, and labor market experience.

Students discount the future at rate $\beta$ and maximize their expected utility subject to the budget constraint. They choose enrollment $s_t \in \{0,1\}$; whether not to work, work only during the summer, or work also during the academic year $h_t \in \{0, \frac{1}{2}, 1\}$; and to take up none of the loan they are eligible for, half, or all of it $\ell_t \in \{0, \frac{1}{2}, 1\}$. Hence, they face ten mutually exclusive and exhaustive choices denoted by index $j \in \{0, \ldots 9\}$: $(s_t, \ell_t, h_t) \in \big\{(0,0,1),(1,0,0),(1,\frac{1}{2},0),(1,1,0),(1,0,\frac{1}{2}),(1,\frac{1}{2},\frac{1}{2}),(1,1,\frac{1}{2}),(1,0,1),(1,\frac{1}{2},1),(1,1,1)\big\}$. Call $d_t \in (d_t^0, d_t^1, d_t^2, d_t^3, d_t^4, d_t^5, d_t^6, d_t^7, d_t^8, d_t^9)$ where $d_t^j$ an index that takes value 1 if the corresponding alternative is chosen and zero otherwise. Students then choose $\{d_t^*\}_{t=1}^T$, a set of decision rules for every possible realization of the observed and unobserved variables each period, denoted by $(X_t, \epsilon_t, \upsilon_t)$ such that:

$$d_t^* = arg \max_j \mathbb{E}\left[\sum_{\tau=t}^{T} \beta^{\tau-t} \sum_{j=0}^{10} \left[d_\tau^j U_\tau^j(X_\tau, \epsilon_\tau)\right]\right]. \tag{2}$$

where $X_t = (A, K, S_0, D_t, G_t, E_t, H_t, h_{t-1}, \ell_{t-1}, t)$ is the vector of observed state variables, and $\epsilon_t$ is the vector of alternative specific preference shock.

By the Bellman principle of optimality, the problem can be rewritten as:

$$V_t(X_t, \epsilon_t) = \mathbb{E}\left[U_t(X_t, \epsilon_t) + \beta V_{t+1}(X_{t+1}, \epsilon_{t+1})\right] \tag{3}$$

and, given the discrete nature of the choices, it can also be written as:

$$\begin{aligned} V_t(X_t, \epsilon_t) &= \max_j \mathbb{E}\left[V_t^j(X_t, \epsilon_t)\right] \\ V_t^j(X_t, \epsilon_t) &= \mathbb{E}\left[U_t^j(X_t, \epsilon_t) + \beta V_{t+1}(X_{t+1}, \epsilon_{t+1}) \mid X_t, \epsilon_t, d_t^j = 1\right] \end{aligned} \tag{4}$$

where $V_t^j(X_t, \epsilon_t)$ denotes the alternative specific value function. The last term is typically referred to as the $\mathbb{E}\max$ as it is the expectation over future optimal values, which makes the solution and estimation of the model challenging. Note that utility after university exit only depends on the choices made during university enrollment and on initial states. This feature is very important in the solution and estimation of the model, leading to a relatively simple expression for the value of university exit and the $\mathbb{E}\max$ in equation (4).

### 5.1.1 Preferences

Individuals gain utility from consumption, college attendance, and the alternative specific shock. The utility of the individual is assumed to be additively separable in the observable state

$X_t$ and $\epsilon_t$.[20] Utility from consumption is of the CIES form $u(c_t) = \frac{1}{\lambda}\left(c_t^{\lambda} - 1\right)$, where $\frac{1}{1-\lambda}$ is the Intertemporal Elasticity of Substitution.

The instantaneous utility of full-time work is as follows:

$$U_t^0(X_t, \epsilon_t^0) = u\left(C_t(X_t)\right) + \epsilon_t^0 \tag{5}$$

where $X_t = (A, K, S_0, D_t, G_t, E_t, H_t, h_{t-1}, \ell_{t-1}, t)$ is the vector of observed state variables. Once individuals exit university, they cannot enroll again – full-time work is assumed to be an absorbing state.

The instantaneous utility of students is given by the CIES utility of consumption and non-pecuniary utility of college attendance.

$$\begin{aligned}
U_t^j(X_t, \epsilon_t^j) =& u\left(C_t(X_t)\right) + n_t + \epsilon_t^j \\
& n_t = \nu_0^m + n_t^d + n_t^h + \nu_1^{js} t \\
& n_t^d = \nu_2^d \mathbf{1}_{\{\ell_{t-1}=1\}} + \nu_3^d \mathbf{1}_{\{\ell_{t-1}=\frac{1}{2}\}} \\
& n_t^h = \nu_4^h A + \nu_5^h K + \nu_6^h \mathbf{1}_{\{h_{t-1}=1\}} + \nu_7^h \mathbf{1}_{\{h_{t-1}=\frac{1}{2}\}} + \nu_8^{hs} E_t
\end{aligned} \tag{6}$$

Utility is determined by student income and aid through current and past consumption. The consumption value of college attendance, $n_t$, can be thought of as the value of learning less the psychological effort cost of studying. This value depends on the type, denoted by the superscript $m$, and on both the loan take-up and the work status of the student, denoted by superscripts $\ell$ and $h$. Working during college may generate a utility loss (or gain). We allow this value of working during college to vary with abilities $A$, skills $K$, level of enrollment $s$, time since college enrollment $t$, and whether the student has graduated $E_t$. Taking up student debt can also generate a utility loss (or gain) that we allow to depend on time since enrollment, $t$, and on level of enrollment $s$. To allow for adjustment costs, we let the work (loan) choice depend on past work (loan) choices, denoted by $h_{t-1}$ and $\ell_{t-1}$.

The alternative specific preference shocks, $\epsilon_t^j$, capture the fact that new information about alternative specific tastes is revealed to students each period, and are i.i.d. type I extreme value.

[20]This assumption is crucial for the CCP method we apply. Keane and Wolpin (1994) and Keane et al. (2011) provide thorough discussions of this assumption.

### 5.1.2 Budget Constraint

Consumption while in college is equal to labor earnings for the workers, $Y_t$, plus study aid (grants and eventually loans) when eligible. Students always take up the grant part of the aid.[21] After college, consumption is equal to labor earnings minus the repayment of any outstanding student debt. The budget constraint can be written as follows:

$$C_t = Y_t + s_t(\widehat{b}(X_t) + \ell_t\widehat{\ell}(X_t)) - (1 - s_t)\widehat{I}(X_t) \tag{7}$$

where for students ($s_t = 1$), $\widehat{b}$ is the grant amount the student is eligible for, $\ell_t \in \{0, \frac{1}{2}, 1\}$ is the loan take-up choice, and $\widehat{\ell}$ is the loan amount the student is eligible for. For those who have exited college ($s_t = 0$), $\widehat{I}_t$ is the student debt installment which is given by the ordained repayment rule. All these amounts were exogenously changed by the reform. The budget constraint is static in the sense that we do not model savings.[22] Budget constraints are, however, intertemporally linked through student debt accumulation and loan repayment.

We model study aid as closely as possible to the scheme described in Section 4 conditional on the information we have in the data. Study aid is thus following the function plotted in Figure 1 and Figure 2 subject to the eligibility requirements described in Section 4. The total amount of study aid is means tested on student income in the current year, $Y_t$, but independent of parental resources. If current income $Y_t$ is above the threshold $\overline{Y}$, then the study aid is taxed at the implicit tax rate $\tau_B$. All students enrolled in college, $s_t = 1$, are eligible for study aid as long as the maximum limit of 240 weeks of student aid is not reached. This corresponds to $\bar{t} = 6$ years in our model. Let $\overline{B}$ denote the maximum base aid amount. The maximum aid amount, $\widehat{B}_t$, the student is eligible for is given by the following rule:

$$\widehat{B}(X_t) = \left[\overline{B} - \tau_B(Y_t - \overline{Y})\mathbf{1}_{\{Y_t \geq \overline{Y}\}}\right]\mathbf{1}_{\{t \leq \bar{t}\}}. \tag{8}$$

The available aid is then divided into a grant share and a loan share. The grant share is denoted by $b$. Thus, the grant amount is given by $\widehat{b}(X_t) = b\widehat{B}(X_t)$, and the maximum base grant amount is $\bar{b} = b\overline{B}$. Similarly, the loan amount students are eligible for is given by $\widehat{\ell}(X_t) = (1-b)\widehat{B}(X_t)$,

[21] The data reveal that less than 2 percent of eligible students turn down the grant, hence in the model and estimation we assume that all eligible students receive the grant. Moreover, the data only include total student aid received during the year. We assume students receive the full grant amount before taking up the loan. In order to calculate the loan amount, we thus subtract the grant amount the student is eligible for from the total study aid observed in the data.

[22] We neither have data on consumption, wealth, nor assets.

and the law of motion of student debt is:

$$D_{t+1} = D_t + \ell_t \widehat{\ell}(X_t). \tag{9}$$

Note that despite the static budget constraint in equation(7), the current loan amount affects the expected future value through the accumulation of debt to be repaid post-college exit, $\widehat{I}$. The rules for loan repayment were drastically changed with the reform in 2001: the payments went from income-contingent to annuities. Before 2001, individuals would repay 4% of their income two years prior, $Y_{t-2}$, until their debt was repaid or they retired. Pre-reform repayment thus follows:

$$\widehat{I}_t(D_{t-1}, Y_{t-2}, r) = max\big\{0, min\{0.04Y_{t-2}, (1+r)D_{t-1}\}\big\}. \tag{10}$$

After 2001, the installments are calculated according to the 25 years-annuity described in equation(1) in Section 4, $\widehat{a}((1+r)D_{t-1})$. Students enrolled prior to fall 2001 are twice allowed to choose to repay 5% of their income for three years and then reset the annuity. Let $I$ denote the indicator function that takes value 1 if the individual has chosen an income-contingent payment at least twice and 0 otherwise. Post-reform repayment thus follows:

$$\widehat{I}_t(D_{t-1}, Y_t, \widehat{a}, r) = \begin{cases} max\big\{0, min\{\widehat{a}((1+r)D_{t-1}), 0.05Y_t\}\big\} & \text{if } I = 0 \\ max\big\{0, \widehat{a}((1+r)D_{t-1})\big\} & \text{if } I = 1. \end{cases} \tag{11}$$

Note that the student debt accumulates interest over time at the rate $r$. The reform changed both the grant share, $b$, the maximum student income threshold, $\overline{Y}$, the implicit tax rate, $\tau_B$, and the enforcement of the duration of study aid, $\bar{t}$.

#### 5.1.3 Academic Environment

We denote the pre-existing individual stock of course credits by $G_t$ and course credits accumulated from $t$ to $t+1$ by $g_t$. Course credits then follow the law of motion: $G_{t+1} = G_t + s_t g_t$. We normalize a completed year of university education to $g_t = 6$ course credits, equivalent to actual ECTS production being $g_t * 10$. We allow the accumulation of course credits to depend on initial abilities $A$ and skills $K$. We also allow course credits to depend on whether the student has already acquired a degree $E_t$ (and is simply continuing to accumulate credits), as well as on the stock of course credits, $G_t$, capturing self-productivity of academic skills (Cunha et al., 2006; Cunha and Heckman, 2008). Finally, course credits depend on time since initial enrollment $t$, on whether the students works only during the summer $h_t = \frac{1}{2}$ or during the academic year as well $h_t = 1$, and on whether the student choose to take up part of the loan $\ell_t = \frac{1}{2}$ or the full loan $\ell_t = 1$. We also include an indicator for the first year of enrollment, as students typically start in September and all other observations are by calendar year. This captures differences in the time period in which course credits are produced. We also allow for full flexibility across levels of initial enrollment, denoted by the superscript $s$. The level parameter $\gamma_0$ is also allowed to vary by type. Production of academic course credits is given by:

$$\begin{aligned} g_t^* &= \gamma_0^{ms} + \gamma_1^s A + \gamma_2^s K + \gamma_3^s E_t + \gamma_4^s G_t + \gamma_5^s t + \gamma_6^s \mathbf{1}_{\{t=0\}} + \gamma_7^s \mathbf{1}_{\{h_t=\frac{1}{2}\}} \\ &\quad + \gamma_8^s \mathbf{1}_{\{h_t=1\}} + \gamma_9^s \mathbf{1}_{\{\ell_t=\frac{1}{2}\}} + \gamma_{10}^s \mathbf{1}_{\{\ell_t=1\}} + \upsilon_t^{gs} \qquad (12) \\ g_t(X_t, d_t, \upsilon_t^{gs}) &= g(g_t^*) \end{aligned}$$

where the unobservable terms $\upsilon_t^{gs}$ are i.i.d. logistically distributed so the probability of producing $g_t$ course credits is of ordered logit form. Course credit production is probabilistic in the sense that students are not sure how many courses they will pass during the academic year about to start. The continuous latent variable $g_t^*$ reflects the academic knowledge acquired during the year, which maps into the eight discrete values: $g_t \in \{0, 1, 2, 3, 4, 5, 6, 7\}$, where $g_t = 7$ captures all credit production above 60 ECTS.

Importantly, we allow students to face uncertainty about how much academic capital they will acquire and also allow it to depend on work status. Joensen (2013b) shows that the relationship between hours worked and academic achievement is nonlinear: a few hours of work have a positive effect on credits production, while working more hours has a detrimental effect. We have less detailed data on hours worked, but better data on the timing of work during the year. We distinguish between working predominantly during the summer months (captured by $\gamma_7$) and also working a significant amount during the semesters (captured by $\gamma_8$). This flexibly allows for different trade-offs between academic performance and the timing of work months.

Because it is common in our population to graduate with more credits than necessary (and because there are cases in which graduation is achieved with fewer credits[23]), we model highest acquired degree as a stochastic function of accumulated course credits. Graduation, $E_t \in \{0, 1\}$ is probabilistic and depends on the level of enrollment, time since initial enrollment, cumulated

[23] This is likely to be due to missing credits due either to misreporting from the University, or to the student being abroad for a period; e.g. in an exchange program.

credits, and an i.i.d. logistically distributed shock $\upsilon_t^e$.

$$E_{t+1} = E_t + \mathbf{1}\left[e_t^* > 0 | E_t = 0\right] s_t. \tag{13}$$

The probability of graduating on a given year depends on time since initial enrollment $t$, on how many semesters worth of credits the students has accumulated so far, and interaction terms between the two. The probability of graduating also depends on the level of enrollment, $S_0 \in \{3, 4\}$, denoted by the superscript $s$.

$$e_t^* = \eta_0^s + \sum_{i=1}^{7} \eta_i^s \mathbf{1}\left[G_{i+1} >= \bar{G}_i\right] + \eta_8^s t + \eta_9^s t^2 + \sum_{i=1}^{7} \eta_{9+i}^s t \mathbf{1}\left[G_{i+1} >= \bar{G}_i\right] + \upsilon_t^{es}. \tag{14}$$

$\bar{G} \in \{12, 15, 18, 21, 24, 27, 30\}$ denotes credit thresholds for every semester after two years worth of credits are completed. One full semester is 3 normalized credits, two years worth of credits is equivalent to $\bar{G} = 12$, two and a half years worth of credits is equivalent to $\bar{G} = 15$, and so on up to 10 semesters of full-time credits, $\bar{G} = 30$. $\bar{G}$ captures discrete jumps in graduation probability when the student completes a semester. Upon graduation, students are not required to leave university and can continue accumulating credits.

#### 5.1.4 Labor Market

Every period, the individuals receive a wage offer with probability $p_w = 1$. Non-students are assumed to work full-time, while students can choose not to work, work only during the summer, or work also during the academic year, $h_t \in \{0, \frac{1}{2}, 1\}$. Working increases the stock of labor market experience according to the law of motion $H_t = H_{t-1} + h_{t-1}$.

Conditional on working, the wage depends on highest acquired degree $E_t$, accumulated course credits $G_t$, and an idiosyncratic labor market productivity shock $\upsilon_t^y$. The wage of a working student ($s_t = 1$) depends on if the students is working only during the summer, $h_t = 1/2$, and linearly on labor market experience, $H_t$. We allow the intercept of the wage equation to be different, $\alpha_4$. Finally, as in the course credit equation, we insert a dummy for the first year of enrollment. The wage of a full-time worker, $s_t = 0$, depends on the logarithm of experience interacted with the highest acquired degree $E_t$ and the level, again denoted by the superscript

$s$. More specifically, earnings are given by:[24]

$$\begin{aligned}\log(Y_t) &= \alpha_0^m + \alpha_1^s E_t + \alpha_2^s G_t + s_t \left[\alpha_3 \mathbf{1}_{\{t=0\}} + \alpha_4 + \alpha_5 \mathbf{1}_{\{h_t=\frac{1}{2}\}} + \alpha_6 H_t\right] \\ &+ (1-s_t)\left[\alpha_7 log(H_t+1)\mathbf{1}_{\{E_t=0\}} + \alpha_8^s log(H_t+1)\mathbf{1}_{\{E_t=1\}}\right] + \upsilon_t^y.\end{aligned} \tag{15}$$

The unobservable term $\upsilon_t^y$ is normally distributed with mean zero and variance $\sigma_y^2$. We are able to separate out the pecuniary importance of degrees and credits by allowing the wage to both depend on highest acquired degree and cumulated course credits during college enrollment. This allows for nonlinearities in the wage return to education: the individuals who have completed a degree receive higher wages than individuals who have completed the course credits necessary to obtain the degree, but who have not actually graduated. This is also known as *sheepskin* effects; if $\alpha_1 = 0$ there would be no such effects.[25] Note that analysing these effects has not been possible in previous papers on college attainment, as Keane and Wolpin (2001) only model 4-year college completion and Johnson (2013) only models 2- and 4-year college completion – both implicitly assume that only degrees matter on the labor market. The availability of detailed data on both degrees and course credits each semester allows us to distinguish between the labor market returns to course credits and degrees.

#### 5.1.5 Enrollment Decision

At $t = 0$, high school graduates decide whether or not to enroll in college and what length of program they will attend if they do choose to enroll. This choice is denoted by $S_0 \in \{0, 3, 4\}$, where 0 denotes no enrollment in college, and 3 and 4 the length of the program conditional on enrollment. The choice is taken by maximizing discounted expected utility from enrollment:

$$W_0(X_0, \epsilon_0^s) = \max_{S_0} \left[\zeta_0^m + \zeta_1^s A + \zeta_2^s K + \zeta_3^s H_0 + \epsilon_0^s + V_0(X_0, \epsilon_0 | S_0)\right]. \tag{16}$$

The non-pecuniary utility from enrollment depends on the type $m$, ability $A$ and skills $K$, labor market experience $H_0$, and alternative specific type I extreme value preference shocks, $\epsilon_0^s$. These initial conditions – high school GPA, math-science track, and labor market experience – encompass the most important factors that college admission is conditioned on. Öckert (2010)

[24] We have also estimated standard Mincer type earnings equations with linear quadratic dependence on experience, however, given that we follow most individuals from having no experience through their very early career the $log(H_t + 1)$ specification fits our earnings-experience profiles much better.

[25] See e.g. Heckman et al. (2006) for a thorough review of non-linearities in the return to education and other specification issues of the earnings equation.

provides a detailed description of the college admission process, while Bjorklund et al. (2005) provide a thorough description of education in Sweden during this period.

#### 5.1.6 Unobserved Heterogeneity

We introduce the additional unobserved state $m$ to relax the i.i.d assumption of the unobservable shocks as well as account for unobserved heterogeneity and dynamic selection. Following Heckman and Singer (1984), the standard approach in the literature is to treat these initial traits as unmeasured and drawn from a mixture distribution (Keane and Wolpin, 1997; Eckstein and Wolpin, 1999; Arcidiacono, 2004; Keane et al., 2011). This way of accounting for unobserved heterogeneity allows for flexible correlation of the errors across the various alternatives as well as correlation over time and dynamic selection.

We thus assume there is a finite mixture of $m = 1, ..., M$ discrete types of individuals who differ in the parameters that describe their preferences, their academic ability and motivation, and their labor market ability. Each type comprises a fixed proportion of the population and is persistent over time. To reduce the number of parameters and avoid identification issues, we only allow for first-order heterogeneity effects. The unobserved state enters linearly in the preferences, as well as in the wage equation and in the course credits production. This way, we allow for self selection into work based on type, and for dependence between choices and wages.[26]

### 5.2 Estimation

Our goal is to estimate the parameters of the law of motions of the course credit production function ($\gamma$) and the graduation probability ($\eta$), and the parameters of the earnings equation ($\alpha$), the utility function ($\nu$ and $\zeta$), and the intertemporal elasticity of substitution ($\lambda$). We set the discount factor to be $\beta = .95$. We use a maximum-likelihood based estimation procedure.

The state variables in $X_t = (A, K, S_0, D_t, G_t, E_t, H_t, , h_{t-1}, \ell_{t-1}, t)$ are also observed by the econometrician, while those in $\epsilon_t = (\epsilon_0^s, \epsilon_t^0, \epsilon_t^1, \epsilon_t^2, \epsilon_t^3, \epsilon_t^4, \epsilon_t^5, \epsilon_t^6, \epsilon_t^7, \epsilon_t^8, \epsilon_t^9)$ and $\upsilon_t = (\upsilon_t^y, \upsilon_t^g, \upsilon_t^e)$ are observed only by the individuals. We make the conditional independence assumption as in Rust (1987), in which we assume that, conditional on today's realization of the state $X_t$ and the choice $d_t$, next period's realization of the state $X_{t+1}$, as well as today's value of earnings $y_t$

[26] This approach is common in the literature; see e.g. Eckstein and Wolpin (1999) or Keane et al. (2011) for a discussion.

are independent of the unobservable shocks $\epsilon_t$. The stochastic components in $\upsilon_t$ are revealed after the choices for the period are made, while the stochastic components in $\epsilon_t$ are revealed before – students therefore observe the deterministic state variables and the preference shocks, $\epsilon_t$, form expectations about the stochastic components of the state and earnings, $\upsilon_t$, and then make decisions.

The conditional independence assumption and additive separability of $\epsilon_t$ assumed in Section 5.1.1 implies separability between the choice probability and the transition for the observable state in the likelihood function. Denoting the vector of parameters to be estimated by $\theta = \{\alpha, \gamma, \eta, \nu, \zeta, \lambda\}$, the likelihood function for every individual $i$ can then be written as:

$$\begin{aligned} L_t(d_{it}, X_{it+1} \mid X_{it}; \theta) = & \, p_0(S_0 \mid X_{i0}; \theta) \times p_t(d_{it} \mid X_{it}; \theta) \times P_t(G_{it+1} \mid X_{it}, d_{it}; \gamma) \times \\ & \times P_t(E_{it+1} \mid X_{it}, d_{it}; \eta) \times P_t(Y_{it} \mid X_{it}, d_{it}; \alpha) \end{aligned} \tag{17}$$

where $p_t(d_{it} \mid X_{it}; \theta)$ is the conditional choice probability (CCP) of the choice $d_{it}$. The entire set of model parameters enters in the likelihood component specific to the utility, whereas the model parameters specific to course credit production, graduation, and wages enter separately in the likelihood components of the states. The separability of the likelihood function allows a sequential maximum likelihood approach. The assumption of Type-1 EV errors for the utility function made in subsection 5.1.1 and the presence of an absorbing state allow us to write a closed-form representation of the value functions as a function of one-period-ahead conditional choice probabilities and the discounted future value of the terminal choice, making the estimation problem substantially more tractable.[27]

On top of the model parameters though, we also want to estimate the distribution on the unobserved types $m$. The separability of the value function is not maintained when we add unobserved heterogeneity: the joint likelihood of the choice $d_{it}$ and the state $X_{it}$, with the addition of the types $m$, becomes a finite mixture of the type-specific likelihood in equation (17):

$$L_t(d_{it}, X_{it+1} \mid X_{it}; \theta) = \sum_{m=1}^{M} \pi(m \mid X_{i0}) L_t(d_{it}, X_{it+1} \mid X_{it}, m; \theta). \tag{18}$$

The probability of being in unobserved state $m$ given the initial state, $X_{n0}$, is denoted by $\pi(m \mid X_{i0})$.

The log likelihood is now no longer additively separable, implying that maximization cannot

[27] Details on this CCP estimator can be found in Arcidiacono and Ellickson (2011). Details on our implementation are in Appendix B.

be done sequentially. However, the expectation-maximization (EM) algorithm simplifies this optimization problem substantially by reintroducing additive separability in the log-likelihood functions through an iterative maximization approach. The EM algorithm splits the problem into two stages and yields a solution to the initial maximization problem upon convergence. It is an iterative process in which the outer loop (expectation step) solves for the distribution of the $m$ types and the population probabilities $\pi$'s, while the inner loop (maximization step) solves for the model parameters, $\theta$. Arcidiacono and Miller (2011) show that the EM algorithm is easily adapted to CCP estimation. We use their algorithm to estimate our model with unobserved heterogeneity. In Appendix B we provide further details on the estimation algorithm.

### 5.3 Choices and Outcomes in the Data

In Table 2 we display the period-by-period choice transitions, which reveal a lot of persistence in most choices. Our absorbing state assumption is reasonable, since 95% of those not enrolled in college and working full-time at $t-1$ are also doing so at $t$.[28] We observe transitions between all the feasible choices, which is important for identification of the model parameters. The only two choices that are not persistent are those involving partial loan ($j_t = 2, 5, 8$). Individuals are very likely to transition from first taking up a partial loan to either the full student loan while not working/working only in the summer or to not taking up any loan while working during the academic year. This could indicate that students are debt averse, and that the partial loan option is a stepping stone for them to eventually take up the full student loan or fund all of their consumption through work.[29]

Figure 9 shows college-to-work transitions by work and loan status. The figure reveals how students gradually flow from college enrollment to working full-time on the labor market ($j = 0$). 70% of students enter the labor market full-time after six years and more than 90% enter ten years after initial enrollment. The most common choice during the first college years is to study and work during the summer while taking up the full available loan ($j = 6$). This

[28]Note that the table is constructed after we code as continuously enrolled students who exit college for a year or less and then re-enroll.

[29]This is consistent with Stinebrickner and Stinebrickner (2008) who take a direct approach of assessing borrowing constraints for low-income students at Berea college. Their survey data reveals that the vast majority of students would not take up a loan if offered to them at the market interest rate. Stinebrickner and Stinebrickner (2008) conclude that borrowing constraints are likely only an important reason for dropping out for some students, but not for the vast majority – even if, among the half of students dropping out, two thirds cite the lack of money being part of the reason. Johnson (2013) also finds that students are reluctant to borrow. Our model incorporates two possible factors underlying this observation: Uncertainty about graduation and being able to comfortably pay back the loan, as well as a switching cost to start borrowing.

Table 2: Choice Transitions

| $j_{t-1}$ | $j_t$ 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 95.16 | 0.36 | 0.13 | 0.41 | 0.78 | 0.32 | 1.21 | 0.90 | 0.15 | 0.59 |
| 1 | 14.82 | 30.62 | 4.42 | 6.36 | 19.16 | 3.81 | 5.82 | 12.14 | 1.02 | 1.84 |
| 2 | 9.13 | 13.23 | 8.35 | 19.04 | 9.27 | 7.33 | 16.96 | 9.52 | 2.34 | 4.85 |
| 3 | 6.95 | 5.06 | 3.72 | 29.73 | 3.36 | 3.25 | 29.11 | 6.58 | 1.91 | 10.34 |
| 4 | 9.09 | 8.71 | 1.71 | 2.37 | 35.18 | 7.60 | 8.95 | 20.64 | 2.46 | 3.30 |
| 5 | 5.94 | 3.36 | 2.45 | 6.94 | 12.60 | 13.11 | 28.88 | 12.63 | 4.71 | 9.39 |
| 6 | 4.42 | 1.23 | 1.03 | 9.49 | 3.19 | 3.99 | 47.02 | 8.24 | 2.80 | 18.60 |
| 7 | 38.59 | 1.26 | 0.21 | 0.62 | 6.00 | 1.61 | 3.86 | 39.34 | 2.58 | 5.94 |
| 8 | 20.06 | 0.96 | 0.48 | 1.66 | 5.34 | 4.63 | 13.27 | 28.36 | 7.73 | 17.50 |
| 9 | 21.75 | 0.46 | 0.24 | 2.21 | 1.78 | 1.71 | 20.80 | 18.58 | 3.59 | 28.65 |

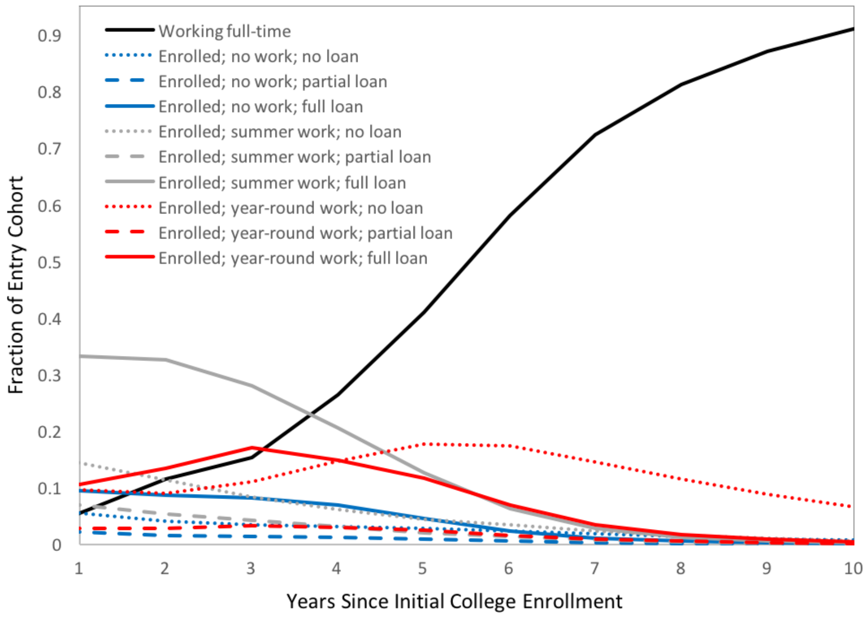
The Table displays student choice transition over time in the data. We number the choices such that $j = 0$ corresponds to no college and full-time work; $j = 1$ to college enrollment, no loan, and no work; $j = 2$ to college enrollment, partial loan take-up, and no work; $j = 3$ to college enrollment, full loan take-up, and no work; $j = 4$ to college enrollment, no loan, and summer work; $j = 5$ to college enrollment, partial loan take-up, and summer work; $j = 6$ to college enrollment, full loan take-up and summer work; $j = 7$ to college enrollment, no loan, and year-round work; $j = 8$ to college enrollment, partial loan take-up, and year-round work; $j = 9$ to college enrollment, full loan take-up, and year-round work.

is followed by studying and working during the summer without taking up any loan ($j = 4$), and then by studying without working or working during the academic year and taking up the full student loan ($j = 3, 9$). All these choices become less popular with time since enrollment, while being a working student and taking up no loan ($j = 7$) becomes increasingly popular; it is the most common choice from the fifth enrollment year onwards.[30] Conforming with eligibility requirements, loan take-up rates fall sharply once it has been six years after initial enrollment.

Figure 10 shows course credit production over time by model choices. Students, working or not working, who do not take up the loan persistently produce fewer course credits (around 30-40 ECTS per year). This may indicate that students with higher ability or higher motivation to study expect a high wage and borrow more because they expect to be able to repay their student debt swiftly after graduation. This is consistent with the descriptives presented in Section 4.2, where those with high expected income $\mathbb{E}[Y]$ take-up more loans both pre- and post-reform. This mechanism should be more important after the reform and the switch from the income-contingent to the annuity-based repayment plan (we will quantify whether or not this is actually the case in our policy simulations). Lastly, the decreasing production of course

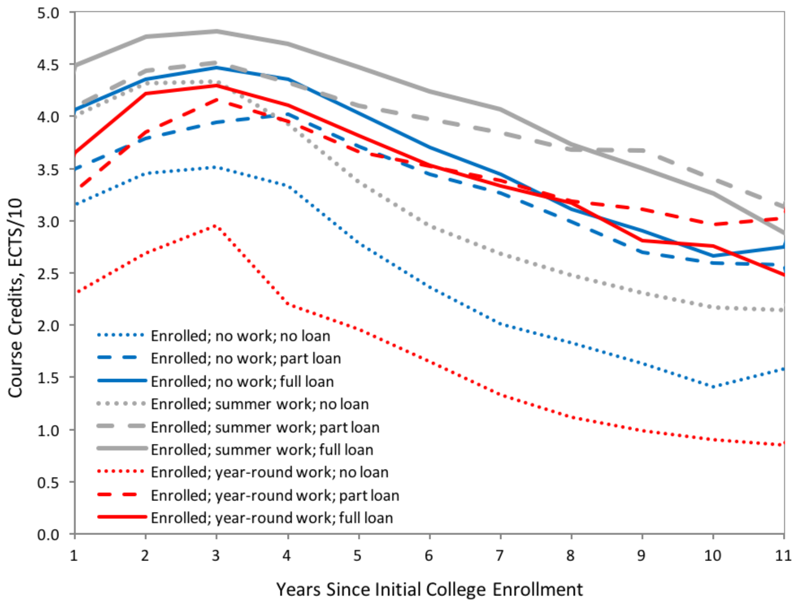
[30]This change is not driven by partial enrollment, which we do not model. Partial enrollment is in principle an option, but according to the data not a popular one among Swedish students. Part-time enrollment increases slightly with time since initial enrollment, but never exceeds 1% of the student population.

Figure 9: College-to-Work Transition




The figure displays the college-to-work transition over the years since initial enrollment (on the x-axis). The fraction of individuals making each feasible model choice of college enrollment, work and loan status, $j = 0, \ldots, 9$, is displayed separately. Black: full-time work and no college enrollment. Blue: no work. Gray: summer work. Red: year-round work. Dotted lines: no loan. Dashed lines: partial loan. Solid lines: full loan.

Figure 10: Course Credit Production over time since initial enrollment




The figure displays actual course credit production per year since initial enrollment (on the x-axis). Average course credit production is displayed separately by the model choices; i.e. by student employment and loan status. One year of full-time studies corresponds to 60 ECTS (on the y-axis). Blue: no work. Gray: summer work. Red: year-round work. Dotted lines: no loan. Dashed lines: partial loan. Solid lines: full loan.

credits over time since enrollment – especially the steep decline around normal graduation years – indicates the importance of accounting for dynamic selection when estimating the model, since students who are more productive will graduate faster.

## 6 Estimation Results

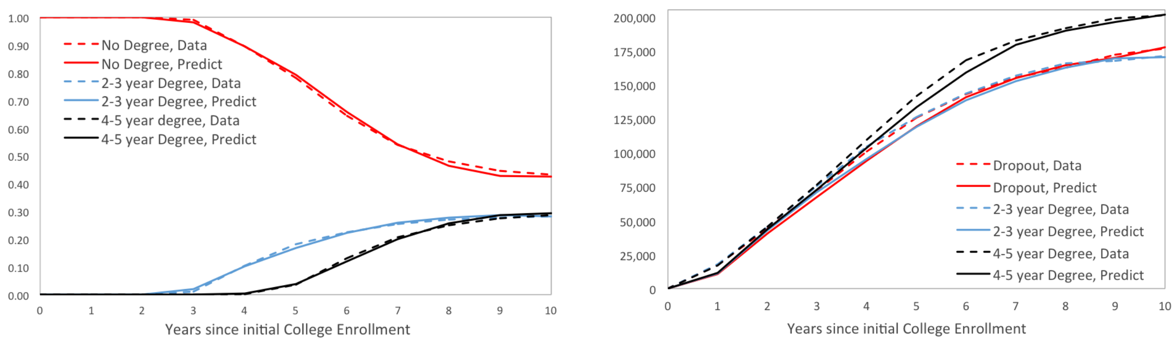
The parameter estimates are presented in Tables 9 and 10 in Appendix D.1. The earnings equation parameters, $\alpha$, reveal that there is a positive degree premium which is larger for longer degrees: a 2-3 year degree increases labor income by 17.4%, while a 4-5 year degree increases labor income by 26.5%. There is a positive earnings effect of accumulated course credits, as one additional course credit increases labor income by 1.5%. This implies that the accumulation of knowledge through course-taking is valued on the labor market, but less so for higher degrees for which the degree premium is higher. Experience has a positive linear effect on wages earned by students. Students working earn significantly lower wages than full-time workers, and students working part-time earn even less. This effect in part captures the differences in hours worked and the likely fact that students work fewer hours than non students. The returns to labor market experience is positive for college graduates from 4-5 year degrees. Students with a 2-3 year degree have a lower return to labor market experience. This seems to reflect the fact that 2-3 year degrees are mostly in lower paying fields and lead to jobs with lower career opportunities; e.g. nurses versus medical doctors in the health sciences.

The parameters of the course credit production function reveal that ability has a positive effect on course credit production. On the other hand, skills show a small effect for shorter programs, which can be due to the fact that there is a positive selection of graduates from the high school science track into longer programs. There is an increasingly negative effect for those who have already acquired a degree, which may reflect the fact that students with a degree are close to exiting college or are taking extra courses not necessary for graduation. Similarly, there is a negative effect for time since first enrollment, capturing both the increasing difficulty of courses as the degree progresses and the possibility of students being less motivated with time. The positive effect of cumulated course credits captures the overall self-productivity of academic skills as already accumulated academic knowledge enhances future academic learning. Working full-time while studying has a negative effect on course credit production, increasing the probability of earning zero credit by 4.4 percentage points (22%) and decreasing the probability of earning six credits by 2.12 percentage points (20%) for 2-3 year programs. On the other hand, only working during the summer has a positive effect, decreasing the probability of earning zero credit by 3.7 percentage points (26%) and increasing the probability of earning six credits by 2.6 percentage points (20%) for 4-5 year programs. This result highlights the fact that the timing of work during the year is crucial. This result is also in line with Joensen (2013a) who finds that the effect of hours worked on academic productivity follows an inverse-U shape, with nine or fewer work hours being beneficial and more than 18 work hours during the week being detrimental.

The parameters that enter the degree probability function confirm that the important thresholds for the 2-3 year degrees are 12 and 18 credits, and the important threshold for the 4-5 year degrees are 21 and 24 credits. However, there is variation in when and with how many credits students graduate – students with fewer credits that are enrolled later are more likely to graduate, which probably reflects missing course credit data.

From the utility function parameters, we learn that students with higher ability and skills have a higher utility of enrollment as would be expected if they have lower study effort costs. Time since initial enrollment lowers the utility of enrollment, indicating that the psychological cost of studying increases with time spent in college. This is capturing the fact that courses can become increasingly challenging towards the end of a degree (because of the curricula or because the student leave the most difficult exams last), that graduation pressure increases as time passes, and that it becomes increasingly likely for peers to have already graduated or dropped out (leading to a diminished campus network). This cost is higher for 4-5 year students and for students who take-up the student loan. Students with a 2-3 year degree have a higher cost to stay enrolled instead of working and earning the degree premium. Students with a 4-5 year degree have a lower cost of staying enrolled. This reflects the fact that they are more likely than 2-3 year students to stay enrolled after graduation. Adjustment costs are important: students who worked the previous year are more likely to work during the year or exit college next period. Students who took up either full or partial loan in the previous period are more likely to stay enrolled and more likely to take-up additional loans. The Intertemporal Elasticity of Substitution (IES) implies a Relative Risk Aversion (RRA) parameter of .16. The risk aversion parameter in the model is identified from the intertemporal trade-off in total income as students choose between three sources of income to finance their college education: labor income, grants, and loans. Grants only increase current income (and less so if labor income

Figure 11: Model Fit




(a) Highest Acquired Degree (b) Student Debt

The figure displays model fit of (a) the highest acquired degree and (b) student debt by highest acquired degree over time. Dashed lines: actual values. Solid lines: predicted values.

is too high) while loans also lower future income as long as there is remaining student debt. The change in the loan repayment plan thus implies an exogenous change in this intertemporal trade-off. The IES (and consequently the RRA) parameter is thus identified by exogenous reform variation. Like Keane and Wolpin (2001) who estimate the RRA to be 0.5, we thus also get a much greater willingness to substitute intertemporally than most of the prior literature. In contrast, Johnson (2013) fixes the RRA parameter at 2. He discusses how his model is not able to capture features of the asset distribution with lower RRA, and still does not capture the thick right tail of student debt with this high RRA.

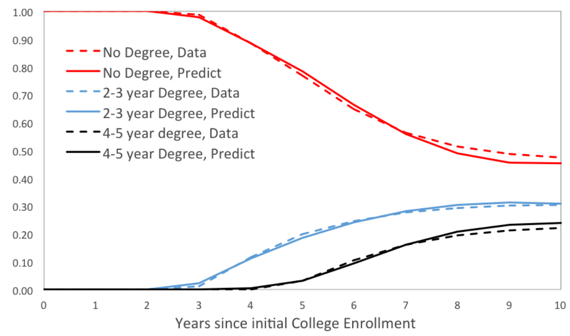
Finally, from the initial enrollment parameters we learn that ability has a positive effect on the enrollment probabilities, while those who attended the high school science track are less likely to enroll in 2-3 year programs and more likely to enroll in 4-5 year programs. Having more labor market experience makes it more costly to enroll in college.

## 6.1 Model Fit

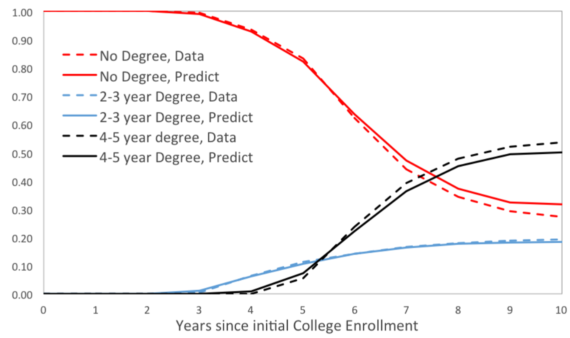
In this section, we assess model fit in order to increase the credibility of our policy simulations. First, we assess in sample and out of sample model fit for the key aspects of our data described in Section 3. Second, we assess whether our model also fits well along important dimensions of heterogeneity that our model is not tailored to fit.

Overall, the model fits key patterns in the data reasonably well. In Figure 11, we show highest acquired degrees over time and student debt by degree – both from the data and the model predictions. We predict well the total level of graduates and non-graduates, as well as

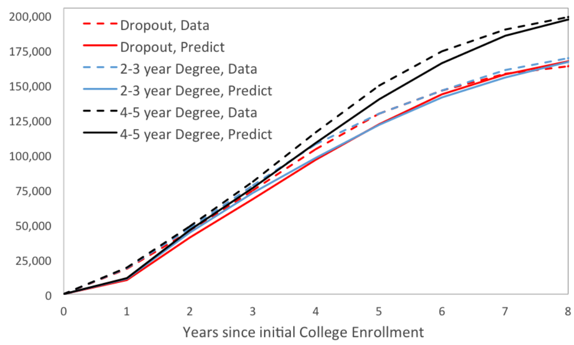
Figure 12: Model Fit, by Ability and Skill



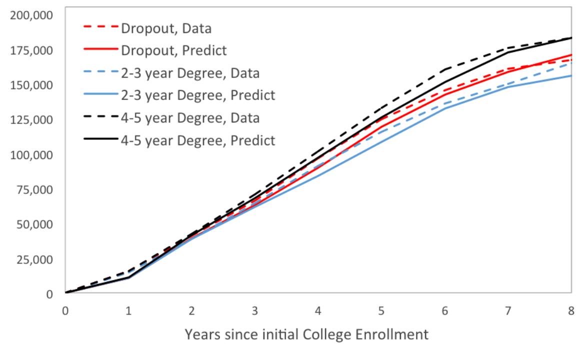

(a) Highest Acquired Degree, Low Ability and Skill




(b) Highest Acquired Degree, High Ability and Skill




(c) Student Debt, Low Ability and Skill




(d) Student Debt, High Ability and Skill

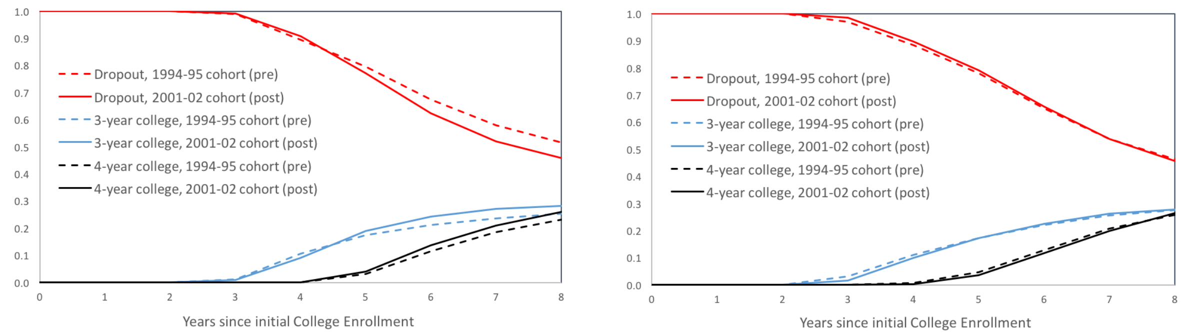
The figure displays model fit of the timing of highest acquired degree and student debt by highest acquired degree. All numbers are displayed separately by the two levels of ability (A) and skill (K) that are initial conditions in our model. Dashed lines: actual values. Solid lines: predicted values.

student debt by degree. Figure 12 shows that the fit is similarly quite good by ability and skill. A good fit of the ability and skill margins is very important since they constitute most of the heterogeneity at college enrollment.[31]

A more challenging in-sample test of our model is how well it fits the differences in student debt and degrees for the cohorts that are exposed only to the pre-reform aid system (1994-1995 cohort) or only to the post-reform aid system (2001-2002 cohort). These cohorts may differ along many dimension of the economic environment (e.g. labor market opportunities) that we do not model, since we are only modeling the differences relating to the reform of the study aid system and our state variables. This model fit is shown in Figures 13 and 14. The model reproduces the difference in student debt between the pre- and post-reform cohorts, while mostly underestimating the magnitude of the debt. Concerning the degrees, however, the

[31]Detailed tables that show model fit across all choices and outcomes of the model can be found in the online Model Fit Appendix.

Figure 13: Model Fit of Highest Acquired Degree, by Pre- and Post-Reform Cohorts

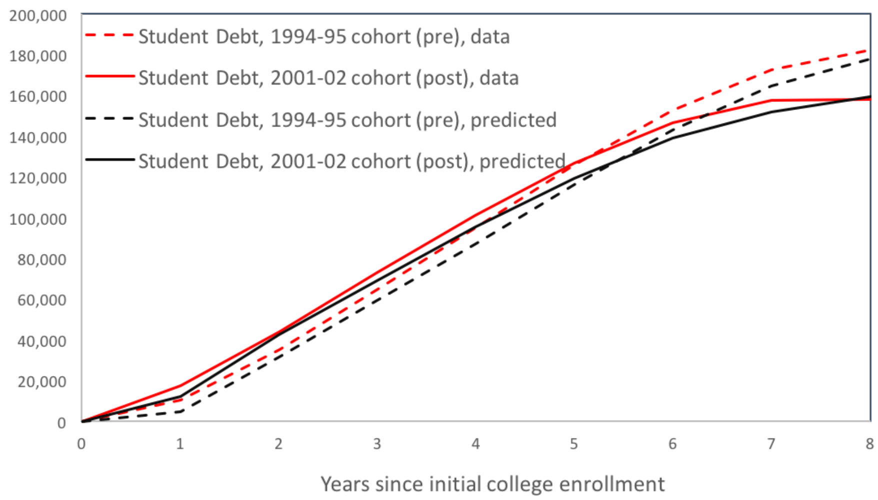



(a) Highest Acquired Degree, Data

(b) Highest Acquired Degree, Predicted

The figure displays model fit of the highest acquired degree for before (1994-1995 cohort) and after (2001-2002 cohort) the reform. The two panels show (a) the data, and (b) the prediction of the model. Dashed lines: pre-reform values. Solid lines: post-reform values.

Figure 14: Model Fit of Student Debt, by Pre- and Post-Reform Cohorts

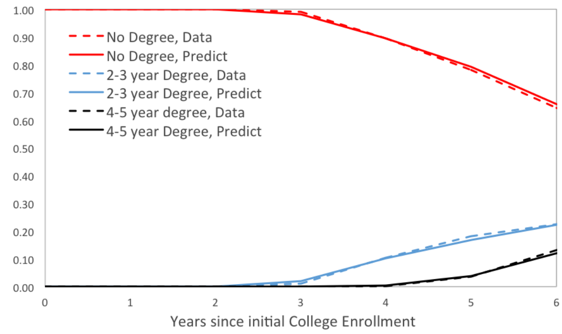



The figure displays model fit of the student debt for before (1994-1995 cohort) and after (2001-2002 cohort) the reform. Red lines: data. Black lines: model predictions. Dashed lines: pre-reform values. Solid lines: post-reform values.

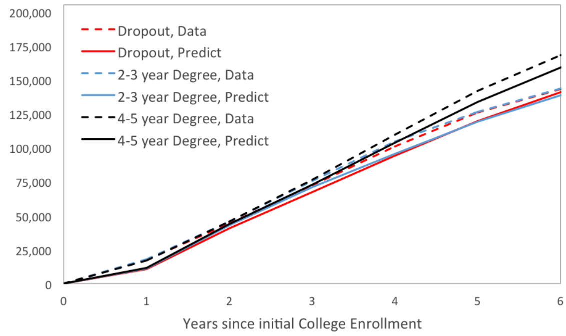
model underestimates the magnitude of the difference in degrees after the 5th year of college enrollment.

To challenge the out-of-sample predictions of our model further, we look at how the model predicts choices and outcomes for individuals that are not included in the estimation. For this reason we hold out two post-reform cohorts of students (2003 and 2004) from our estimation sample. In Figure 15, we show highest acquired degrees over time and student debt by degree. In Figure 16 we show highest acquired degrees and student debt by ability and skill. Our model

Figure 15: Out-of-Sample Model Fit



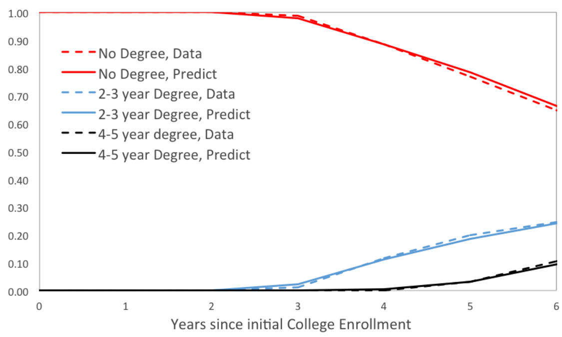

(a) Highest Acquired Degree



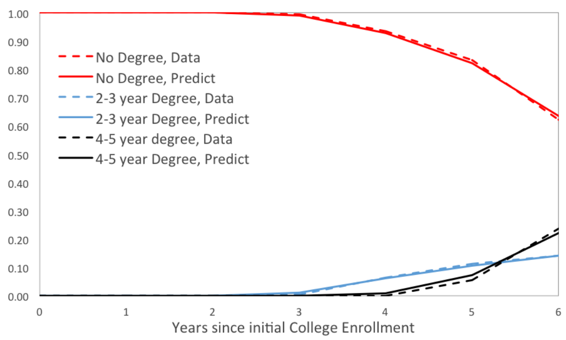

(b) Student Debt

The figure displays model fit of (a) the highest acquired degree and (b) student debt by highest acquired degree over time. Dashed lines: actual values. Solid lines: predicted values.

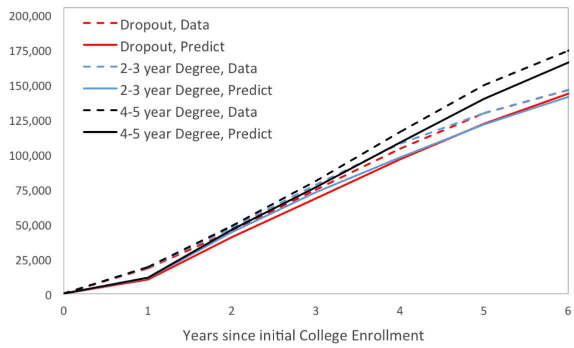
Figure 16: Out-of-Sample Model Fit, by Ability and Skill



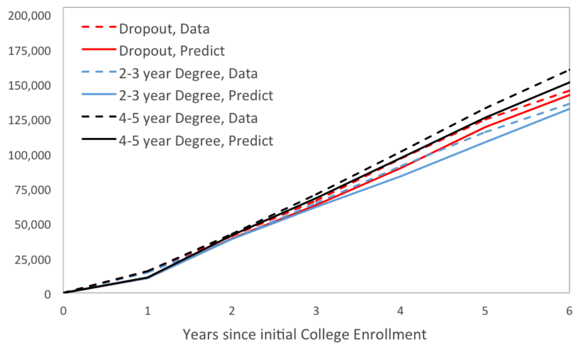

(a) Highest Acquired Degree, Low Ability and Skill




(b) Highest Acquired Degree, High Ability and Skill




(c) Student Debt, Low Ability and Skill




(d) Student Debt, High Ability and Skill

The figure displays model fit of the timing of highest acquired degree and student debt by highest acquired degree. All numbers are displayed separately by the two levels of ability (A) and skill (K) that are initial conditions in our model. Dashed lines: actual values. Solid lines: predicted values.

predicts both degrees and student debt over time for the two cohorts entering college after the cohorts in our estimation sample.

Our model is parsimonious in the dimensions of initial heterogeneity: ability, skill, and labor market experience $(A, K, H_0)$. However, parental characteristics have been shown in the literature to be important determinants education outcomes. We can link our estimates to various parental and individual characteristics of the students and assess how our model fits conditional on them. The dimensions of heterogeneity we examine are field of study, parental income and education, co-residence with parents, cost of living, and gender. Figures that show both in sample and out-of-sample model fit for highest acquired degrees and student debt along all these dimensions can be found in Appendix C.2, and detailed tables can be found in the online Model Fit Appendix. From the figures in Appendix C.2 it transpires that we model enough initial heterogeneity – particularly through A and K – to capture the differences in choices and outcomes across most of the important dimensions of heterogeneity that we do not model. The three subgroups for which our model does not accurately predict behavior are students who co-reside with their parents, and students enrolled in Education, Humanities and Arts, and Health Science, Health and Social Care. Note that, in this case, we assess model fit of the most parsimonious one type model. The model with unobserved heterogeneity will inevitably improve model fit.

## 7 Policy Simulations

In this section, we use the model to construct counterfactuals to assess the ex-ante effects of different study aid policies.[32] We perform three sets of counterfactual policy simulations: First, we change the means testing. Second, we change the repayment plans. Finally, we change the grant share. We simulate how changing each policy instrument would affect student behavior, human capital and debt accumulation. Tables 3, 4, and 5 show the simulated impact of these study aid policies. The first column in each table shows the benchmark choices, outcomes, and policy parameters; i.e. a simulation using the 2001 pre-reform study aid system. All policy simulations start from the same distribution of student initial characteristics in terms of ability, skill, and experience while the interest rate and the aid amounts are fixed at the 2001 value. We also show the impact of the policies on overall aid costs, discounted future utility at exit, and a measure of income inequality: the ratio between the 90th and the 10th percentiles of income at college exit.

[32]Details on the simulation algorithm are in Appendix B.1.

Table 3: Policy Simulations, Means Testing

| | **Reform** | | **Means Testing** | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Pre** | **Post** | **0.0001** | **0.25** | **0.5** | **1** | **1.25** | **2** |
| **Enrollment:** | | | | | | | | |
| 2-3 year Program | *0.3496* | 0.0028 | -0.0196 | -0.0007 | 0.0005 | -0.0007 | -0.0006 | -0.0007 |
| 4-5 year Program | *0.2958* | 0.0011 | -0.0113 | -0.0005 | 0.0002 | -0.0005 | -0.0004 | -0.0005 |
| **Academic Outcome:** | | | | | | | | |
| Dropout | *0.3926* | 0.0168 | 0.0600 | 0.0405 | 0.0040 | 0.0075 | 0.0107 | 0.0052 |
| 2-3 year Degree | *0.3026* | -0.0076 | -0.0320 | -0.0193 | -0.0013 | -0.0045 | -0.0057 | -0.0019 |
| 4-5 year Degree | *0.3048* | -0.0092 | -0.0280 | -0.0212 | -0.0027 | -0.0030 | -0.0050 | -0.0033 |
| Weeks to Dropout | *201* | -1 | -7 | -5 | 0 | 0 | 0 | 1 |
| Weeks to 2-3 year D. | *226* | -2 | -6 | -5 | -1 | -1 | -1 | -1 |
| Weeks to 4-5 year D. | *293* | 0 | -1 | -1 | -1 | 0 | 0 | 2 |
| **Avg Yearly Aid:** | *38,590* | 3,934 | -26,658 | -11,356 | -4,042 | 2,170 | 3,467 | 6,168 |
| **Debt at Exit:** | *154,311* | -5,150 | -108,228 | -47,400 | -16,073 | 7,780 | 12,446 | 23,965 |
| Dropout | *131,756* | -3,391 | -94,097 | -40,083 | -13,572 | 6,656 | 11,051 | 20,844 |
| 2-3 year Degree | *149,777* | -5,052 | -102,492 | -42,360 | -14,308 | 7,513 | 11,904 | 22,577 |
| 4-5 year Degree | *188,587* | -5,399 | -129,613 | -58,405 | -20,656 | 10,459 | 16,296 | 30,625 |
| **Income at Exit:** | *311,432* | -4,082 | -9,002 | -5,846 | -1,466 | -1,631 | -3,435 | -2,096 |
| Dropout | *263,729* | -2,810 | -3,594 | -2,420 | -1,806 | -488 | -2,058 | -1,325 |
| 2-3 year Degree | *292,607* | -3,361 | -4,909 | -1,233 | 614 | -339 | -2,470 | -1,062 |
| 4-5 year Degree | *393,375* | -1,613 | -5,248 | -4,014 | -1,883 | -2,667 | -3,414 | -2,007 |
| **Student Choices:** | | | | | | | | |
| Year-round Work | *0.2946* | 0.0370 | 0.0435 | 0.0341 | 0.0008 | 0.0169 | 0.0357 | 0.0682 |
| Summer Work | *0.5076* | -0.0272 | -0.1020 | -0.0615 | -0.0026 | -0.0120 | -0.0258 | -0.0501 |
| Full Loan | *0.6955* | -0.0008 | -0.0149 | -0.0080 | -0.0014 | 0.0024 | 0.0062 | 0.0128 |
| Partial Loan | *0.1159* | 0.0004 | 0.0095 | 0.0054 | 0.0002 | -0.0003 | -0.0009 | -0.0017 |
| **Cost:** | | | | | | | | |
| per Student | *124,258* | 17,931 | -88,805 | -40,601 | -14,686 | 7,364 | 11,680 | 22,702 |
| Total (%) | - | 15.1277 | -72.7808 | -32.7119 | -11.6912 | 5.7363 | 9.2258 | 17.7598 |
| p90/p10 of Income | *12.1547* | 0.0127 | 0.0196 | 0.0572 | -0.0158 | -0.0739 | 0.0045 | 0.0854 |
| Discounted Utility (%) | - | -0.6117 | -0.1240 | -0.6758 | 0.0405 | -0.3143 | -0.5196 | -0.6372 |
| **Means Testing:** | 0.75 | 1.25 | 0.0001 | 0.25 | 0.5 | 1 | 1.25 | 2 |
| **Grant Share:** | 27.8% | 34.5% | 27.8% | 27.8% | 27.8% | 27.8% | 27.8% | 27.8% |
| **Loan Repayment:** | IC4 | 25year | IC4 | IC4 | IC4 | IC4 | IC4 | IC4 |
| **Maximum Aid:** | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 |

The Table displays policy simulations of the pre- and post-reform periods, and of the effects on student choices and outcomes of changing the means testing in the aid package. We display differences from the benchmark values, and percentage differences from the benchmark for Total Cost and Discounted Utility. The benchmark is the pre-reform year 2001, the values for the benchmark are in levels. In the post-reform simulation we change the means testing, the grant share, and the loan repayment, and we keep everything else at the benchmark level. In the means-testing simulations we change the percentage of the *prisbasbelopp* that determines the semestral threshold and the implicit income tax. All other policy instruments are kept at the benchmark (pre-reform) 2001 level. All amounts are in real SEK 2000. The exchange rate ultimo December 2000 was 9.3955 SEK/USD and 8.8263 SEK/EUR.

The first two columns of Table 3 directly compare the pre- and post-reform study aid systems. The simulations align with the reform variation presented in Section 4 – student year-round work increases, full loan take-up decreases, and student debt decreases. These behavioral changes imply slightly lower income potential and academic capital at exit as dropout rates increase by 1.7 percentage points and 2-3 (4-5) year graduation rates decrease by 0.8 (0.9) percentage points.

### 7.1 Means-testing

Table 3 reveals the effects of changing the means testing, which directly changes the work disincentive in the study aid scheme. We change the percentage of the *prisbasbelopp* that determines the semestral threshold and the implicit income tax. The first three simulations increase the work disincentive by reducing the threshold from 0.75 to 0.50, 0.25, and 0.0001 times the *prisbasbelopp* – the last one essentially means that students do not receive aid if they work. The last three simulations reduce the work disincentive by increasing the threshold for allowable earnings from 0.75 to 1.00, 1.25, and 2 times the *prisbasbelopp*.[33] Overall, the labor supply response is as expected: the slacker the means testing, the higher the share of students working year-round. In turn, this means higher student debt at college exit and longer enrollment spells. When the work disincentive generated by the means testing gets less strict, students work more while still taking up the subsidized loan. This means that the cost of staying enrolled is lower, so they stay enrolled longer, more graduate, but also accumulate more debt. On the other hand, if we take away the possibility of both working and receiving aid at the same time – by imposing a threshold very close to zero – we increase dropout rates by 6 percentage points and decrease both 2-3 and 4-5 year graduation rates by 3.2 and 2.8 percentage points, respectively. Enrollment also decreases by 3.1 percentage points. Students also work less: while year-round work increases by 4.4 percentage points, summer work decreases by 10.2 percentage points. Working during the summer has a large cost in terms of zero student aid and lower yearly income, so students prefer to either work year-round or not work at all when the trade-off between income and aid is at its strongest. Thus not allowing any amount of work when receiving study aid would dramatically increase dropouts rates and increase inequality. Overall, more generous (stricter) means-testing increases (reduces) student debt and the direct cost of study aid for the government is always lower with stricter means testing. The policy simulations in Table 3 show that an intermediate amount of means-testing (0.75) on student income balances the incentives to work and accumulate academic capital as graduation rates and overall human capital is the highest when the means-testing is close to the pre-reform level. These policy responses are largest for those who acquire more academic capital, which means that income inequality is minimized and overall discounted utility is maximized at this intermediate level of means-testing.

[33] Slacking the means-testing further to 5 times the *prisbasbelopp* essentially does not alter student behavior – suggesting that student labor supply is not restricted by the means-testing once it reaches 2 times the *prisbasbelopp*.

Table 4: Policy Simulations, Repayment Plans

| | | Income Contingent | | | Annuity | |
|---|---|---|---|---|---|---|
| | **Pre-reform** | **IC5** | **IC10** | **IC12.5** | **25 years** | **15 years** |
| **Enrollment:** | | | | | | |
| 2-3 year Program | *0.3496* | -0.0002 | -0.0005 | -0.0007 | 0.0027 | -0.0070 |
| 4-5 year Program | *0.2958* | -0.0001 | -0.0004 | -0.0004 | 0.0014 | -0.0044 |
| **Academic Outcome:** | | | | | | |
| Dropout | *0.3926* | 0.0040 | 0.0080 | 0.0088 | 0.0050 | 0.0235 |
| 2-3 year Degree | *0.3026* | -0.0021 | -0.0049 | -0.0054 | -0.0022 | -0.0144 |
| 4-5 year Degree | *0.3048* | -0.0018 | -0.0032 | -0.0035 | -0.0029 | -0.0091 |
| Weeks to Dropout | *201* | 0 | 0 | -1 | 0 | -3 |
| Weeks to 2-3 year D. | *226* | -1 | -2 | -2 | -1 | -3 |
| Weeks to 4-5 year D. | *293* | 0 | 0 | 0 | 0 | -1 |
| **Avg Yearly Aid:** | *38,590* | -157 | -355 | -384 | -208 | -1,105 |
| **Debt at Exit:** | *154,311* | -1,114 | -2,475 | -2,677 | -1,587 | -7,414 |
| Dropout | *131,756* | -560 | -1,567 | -1,749 | -573 | -5,530 |
| 2-3 year Degree | *149,777* | -1,183 | -2,377 | -2,519 | -1,722 | -6,622 |
| 4-5 year Degree | *188,587* | -1,322 | -2,873 | -3,078 | -2,132 | -8,193 |
| **Income at Exit:** | *311,432* | -429 | -1,086 | -1,556 | -958 | -2,771 |
| Dropout | *263,729* | 331 | -370 | -445 | -716 | -107 |
| 2-3 year Degree | *292,607* | -807 | -744 | -1,221 | -1,356 | -3,148 |
| 4-5 year Degree | *393,375* | -91 | -473 | -1,293 | -755 | -607 |
| **Student Choices:** | | | | | | |
| Year-round Work | *0.2946* | 0.0030 | 0.0070 | 0.0078 | 0.0037 | 0.0241 |
| Summer Work | *0.5076* | -0.0023 | -0.0053 | -0.0057 | -0.0026 | -0.0181 |
| Full Loan | *0.6955* | -0.0021 | -0.0047 | -0.0049 | -0.0027 | -0.0141 |
| Partial Loan | *0.1159* | 0.0004 | 0.0012 | 0.0013 | 0.0002 | 0.0059 |
| **Cost:** | | | | | | |
| per Student | *124,258* | -6,228 | -14,238 | -15,565 | -3,216 | -52,546 |
| Total (%) | - | -5.0495 | -11.5881 | -12.6806 | -1.9762 | -43.3155 |
| p90/p10 of Income | *12.1547* | -0.0215 | -0.0534 | -0.0585 | -0.0689 | -0.0126 |
| Discounted Utility (%) | - | -0.2945 | -0.5914 | -0.6297 | -0.2379 | -2.0914 |
| **Means Testing:** | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| **Grant Share:** | 27.8% | 27.8% | 27.8% | 27.8% | 27.8% | 27.8% |
| **Loan Repayment:** | IC4 | IC5 | IC10 | IC12.5 | 25year | 15year |
| **Maximum Aid:** | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 |

The Table displays policy simulations of the effects on student choices and outcomes of changing the repayment plan in study aid packages. We display differences from the benchmark values, and percentage differences from the benchmark for Total Cost and Discounted Utility. The benchmark is the pre-reform year 2001, the values for the benchmark are in levels. All other policy instruments are kept at the benchmark level. All amounts are in real SEK 2000. The exchange rate ultimo December 2000 was 9.3955 SEK/USD and 8.8263 SEK/EUR. The means testing shown in the table is the percentage of the *prisbasbelopp* that determines the semestral threshold and the implicit income tax. The 25(15) years-annuity plan has the possibility of switching to an income contingent repayment of 5% of income, and then going back to a new 25(15) years-annuity calculated on the remaining debt.

## 7.2 Repayment Plans

Table 4 shows the results of changing the loan repayment plan. First, we explore different income-contingent plans, where the installments are 5%, 10%, and 12.5% of income, respectively. Second, we implement the 25 years annuity implemented with the reform and a shortened 15 years annuity. We find that all these counterfactual repayment plans slightly reduce student debt at exit, study aid cost to the government, income inequality at exit, and student discounted utility.

Income-contingency of repayments exhibits and elasticity of -0.72 for debt and -0.14 for income at exit, but is marginally decreasing such that increasing the implicit tax rate on post-college income by 1 percentage points (from 4% to 5%) has just less than half the impact of increasing it by 6 percentage points (from 4% to 10%) which reduces debt at exit by 1.60% and income potential at exit by 0.35%. It is not surprising that students take up less debt when it becomes more costly, but students tend to compensate by working more such that they accumulate less academic capital and consequently have a lower income potential at college exit. These forces are weaker for dropouts than for college graduates, which implies that increasing income-contingency reduces income inequality; for example, increasing the implicit tax rate by 1 (6) percentage points – from a baseline level of 4% – reduces the P90/P10 income fraction by 0.26% (0.44%) from a baseline of 12. Further increases in income-contingency have little impact on outcomes because of the decreasing marginal responses as the implicit tax rate increases beyond 10%. Proponents of income-contingent repayment plans typically focus on the insurance aspect of it for those who get bad labor market draws after college exit, but our results suggest that their adverse effects on human capital accumulation should also be considered.

We find that moving from the pre-reform 4% income-contingent repayment plan (IC4) to the 25 year annuity implemented after the reform has little impact. Students finance slightly less of their studies through debt and more through year-round work, which has a slight adverse effect on academic capital and income potential at exit. This is as expected since, as we document in Section 4, the average repayment plan did not significantly change with respect to the benchmark. However, students expecting lower income (e.g. college dropouts) face higher repayment rates and are pushed to drop out earlier and with less debt. Analyzing differences by initial conditions also reveals that those with low ability and non-science high school degrees, $(A, K) = (0, 0)$, are closer to the dropout margin such that their academic capital responds more to changes in the repayment scheme – despite their work and loan take-up behavior responding less than those with high ability and science high school degrees, $(A, K) = (1, 1)$. Implementing the shorter 15 year annuity has a larger impact as the dropout rate increases by 2.4 percentage points, while the timing of dropout decreases by three weeks. 19 percentage points more students work year-round and finance education through labor income rather than the loan, 1.4 percentage points fewer students take the full loan and student debt at exit decreases by around SEK 7,414. Frontloading repayment plans thus allows the policy maker to lower aid costs and recuperate costs faster, but at the cost of increased dropout rates.

Table 5: Policy Simulations, Grant Share

| | | Grant Share | | | | | |
|---|---|---|---|---|---|---|---|
| | **Pre-reform** | **15%** | **35%** | **45%** | **55%** | **75%** | **95%** |
| **Enrollment:** | | | | | | | |
| 2-3 year Program | *0.3496* | -0.0017 | 0.0009 | 0.0024 | 0.0037 | 0.0064 | 0.0097 |
| 4-5 year Program | *0.2958* | -0.0004 | 0.0002 | 0.0005 | 0.0008 | 0.0016 | 0.0024 |
| **Academic Outcome:** | | | | | | | |
| Dropout | *0.3926* | -0.0056 | 0.0022 | 0.0037 | 0.0030 | 0.0020 | -0.0003 |
| 2-3 year Degree | *0.3026* | 0.0013 | -0.0006 | 0.0004 | 0.0023 | 0.0054 | 0.0091 |
| 4-5 year Degree | *0.3048* | 0.0042 | -0.0016 | -0.0040 | -0.0053 | -0.0074 | -0.0088 |
| Weeks to Dropout | *201* | 1 | 0 | 0 | 0 | 0 | 0 |
| Weeks to 2-3 year D. | *226* | 0 | -1 | 0 | 0 | 1 | 2 |
| Weeks to 4-5 year D. | *293* | 0 | 0 | 0 | 0 | 0 | 0 |
| **Avg Yearly Aid:** | *38,590* | -858 | 580 | 1,497 | 2,520 | 4,803 | 7,396 |
| **Debt at Exit:** | *154,311* | 30,387 | -16,406 | -38,560 | -60,158 | -102,502 | -144,021 |
| Dropout | *131,756* | 25,036 | -13,691 | -32,426 | -50,787 | -87,068 | -122,851 |
| 2-3 year Degree | *149,777* | 29,477 | -15,903 | -37,307 | -58,333 | -99,475 | -139,783 |
| 4-5 year Degree | *188,587* | 37,246 | -20,189 | -47,326 | -73,791 | -125,506 | -176,099 |
| **Income at Exit:** | *311,432* | 1,026 | -711 | -1,029 | -1,151 | -794 | -1,165 |
| Dropout | *263,729* | 522 | -77 | -1,037 | 521 | -567 | 1,067 |
| 2-3 year Degree | *292,607* | 716 | -431 | 369 | -141 | 1,957 | -118 |
| 4-5 year Degree | *393,375* | -8 | -1,090 | -1,994 | -2,235 | -1,156 | -2,144 |
| **Student Choices:** | | | | | | | |
| Year-round Work | *0.2946* | 0.0011 | -0.0016 | -0.0050 | -0.0095 | -0.0190 | -0.0295 |
| Summer Work | *0.5076* | 0.0002 | 0.0009 | 0.0027 | 0.0053 | 0.0109 | 0.0171 |
| Full Loan | *0.6955* | 0.0098 | -0.0049 | -0.0112 | -0.0171 | -0.0290 | -0.0401 |
| Partial Loan | *0.1159* | -0.0028 | 0.0008 | 0.0023 | 0.0034 | 0.0056 | 0.0075 |
| **Cost:** | | | | | | | |
| per Student | *124,258* | -11,870 | 8,311 | 21,742 | 37,044 | 71,244 | 109,151 |
| Total (%) | - | -9.8105 | 6.8783 | 18.0117 | 30.6583 | 59.1562 | 91.1013 |
| p90/p10 of Income | *12.1547* | -0.021 | -0.0142 | -0.0039 | 0.0259 | -0.0196 | -0.0151 |
| Discounted Utility (%) | - | -0.0678 | 0.0597 | 0.2266 | 0.5258 | 1.1763 | 1.9695 |
| **Means Testing:** | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| **Grant Share:** | 27.8% | 15.0% | 35.0% | 45.0% | 55.0% | 75.0% | 95.0% |
| **Loan Repayment:** | IC4 | IC4 | IC4 | IC4 | IC4 | IC4 | IC4 |
| **Maximum Aid:** | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 |

The Table displays policy simulations of the effects on student choices and outcomes of changing the grant share in study aid packages. We display differences from the benchmark values, and percentage differences from the benchmark for Total Cost and Discounted Utility. The benchmark is the pre-reform year 2001, the values for the benchmark are in levels. All other policy instruments are kept at the benchmark level. All amounts are in real SEK 2000. The exchange rate ultimo December 2000 was 9.3955 SEK/USD and 8.8263 SEK/EUR. The means testing shown in the table is the percentage of the *prisbasbelopp* that determines the semestral threshold and the implicit income tax.

In Tables 11 and 12 in Appendix D.2 we show how subsidizing student loans more – by lowering interest rates – makes students finance more of their college costs through debt. Changing the interest rate does not affect student outcomes and choices much when the repayment is income-contingent because the differential human capital accumulation incentives by income potential pulls in opposite directions. When the repayment plan is annuity-based, however, decreasing (increasing) the interest rate by 2 percentage points results in an decrease (increase) in the dropout rate of 0.7-0.8 percentage points and increase (decrease) in the 4-5 year college graduation rate of 0.2-0.3 percentage points.

### 7.3 Grant Share

Table 5 shows the impact of implementing policies that only change the grant share in study aid. We show simulations with the grant share from 15% to 95% of total aid. Changing the grant share has no economically significant impact on dropout and graduation rates. The only substantial impact is on student debt accumulation, where students cumulate around SEK 70,000 less debt when the grant share is 30 percentage points higher. This is interesting from the perspective of policy makers, since they can decide whether to privately (by the individual student) or publicly (by the government) fund college education – without altering education outcomes much. Changing the grant share, however, does alter student behavior such that increasing the grant share means less (more) loan take-up and year-round (summer) work. This means that students have less human capital at exit when the grant share is higher, but their discounted utility is higher – because of their lower student debt – when the grant share is higher. The behavioral response implies that there is a small non-linear effect on academic capital accumulation, since students make more optimal work choices as the grant share increases. This means that academic capital is maximized with a grant share around 65% as grant share over this threshold means that students with $(A, K) = (0, 0)$ become more likely to acquire 2-3 year degrees.

Lastly, we want to highlight some important interactions between policy instruments. In Tables 13 and 14 in Appendix D.2 we show the effects of changing the grant share starting, respectively, from a baseline economy with a 25 year annuity repayment plan and a baseline economy with income contingent repayment plan with a 10% repayment rate. The effects of changing the grant share in both sets of simulations are in line with the ones presented in Table 5 – students are generally less responsive to the grant share with a IC10 repayment plan instead of IC4. With IC10, the academic capital is maximized around 45-55% (rather than 65%) as $(A, K) = (0, 0)$ student accumulate more human capital at exit and $(A, K) = (1, 1)$ students accumulate less academic capital at exit. This results also highlights how a stronger income contingency favors the human capital accumulation of students with low ability and skills such that the income distribution is most compressed with a grant share of 45-55%. On the other hand, income inequality increases with the annuity repayment plan. Repayment plans thus also have to be considered when analyzing the (distributional) effects of changing the grant share.

## 8 Conclusions

The design of financial aid to students has an impact on the incentives to study and work during college, as well as a substantial impact on the budget set both during and after college – as is the case when student loans are an important component of aid. In this paper, we shed light on these behavioral and economic effects of study aid policies. We model students' choices of enrollment, work, and student loan take-up in a structural dynamic model with observed and unobserved heterogeneity.

We find that it is pivotal to have good estimates of how many students are at the relevant margins of choice, how strongly they respond to the financial incentive, *and* how this relates to their outcomes. We show that changes in the grant share have little impact on academic capital under income-contingent repayment plans, but a large impact on student debt at exit. This means that the government can largely decide who bears the college cost by changing the grant share without affecting human capital accumulation. We also find that interactions between policy instruments are important to consider; e.g. changing the grant share when the repayment plan is income-contingent (annuity based) reduces (increases) income inequality. This suggests that existing estimates in the literature that only focus on one policy instrument and fail to account for alternative funding channels may be biased. We also highlight that it is important to both consider shorter- and longer-term effects of study aid policies; e.g. we confirm that income-contingent repayment plans can play an equalizing role, but also shed light on their adverse effects on human capital accumulation.

Overall, the policy instruments work on different margins, different subgroups of students, and have different distributional effects. The work margin tends to be more elastic as students react to changes in aid policies by changing how much they work during college, and less strongly by changing their student loan take-up. As a consequence, policies that directly affect work incentives (e.g. means-testing) are more effective in changing academic outcomes than those that affect budget sets through how loans are designed.

Our results are a step in the direction of better understanding the mechanisms driving student debt accumulation, study, and work behavior, as well as how they are affected by aid policies. More can be done starting from the setting in our paper, such as investigating the dynamics of major choice, the role of parental transfers, and heterogeneity along various skill dimensions and initial conditions. There could also be some fruitful extensions that model student loans in a more realistic labor (and financial) market setting to study potential impacts of aid policies on post-college labor market outcomes and careers over the life-cycle.

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# Appendices

## A Data

### A.1 Sample Selection

Our dataset contains the cohorts of students who graduated from high school in the years 1990-2004. Out of the 1,202,062 students who graduated from high school in that time period, 661,297 (55%) enrolled in a university program or course at some point. Because the quality of the college data improves after 1993, we start our dataset with students who enrolled in college in 1994. Of those who enrolled, 369,886 individuals enrolled in 1994-2004 and were 22 years old or younger at initial enrollment. Out of these 369,886, we drop an additional 11,358 students who enrolled in one of the private universities that do not report credits information (further details on these universities in Section A.3) as well as 846 students that have missing high school GPA information. Of the total 735,048 high school graduates who do not enter in our sample of college students, we drop 285,678 that graduated from high school in years other than 1994-2002, 14,140 that graduated when older than 20 years old, 19,096 who were younger than 22 but who enrolled in non-relevant years, an extra 5,361 for enrolling when older than 22 in one of the institutions that do not report course credit information, and 340 that have missing high school GPA information. Out of these 410,533 non-college students, 98,989 enrolled in a university program or course when they were older than 22. The final dataset contains the cohorts of students who graduated from high school in the years 1994-2002 and are younger than 23 years old by the end of their initial enrollment year. This amounts to 228,424 individuals and 3,352,227 yearly observations on their education, labor market choices, and outcomes until 2009. To conduct out-of-sample model fit, we add 70,457 students enrolled in 2003 and 2004; i.e. 453,009 observations. To account for the initial enrollment choice, we also include all high school graduates from the 1994-2002 cohorts who were not older than 20 when graduating from high school and who had not enrolled in college by the time they were 23 years old. In total, our sample includes 771,487 individuals and a total of 3,805,236 yearly observations.

Figure 17 shows the structure of our sample. We have data from 1994 to 2009, which means that we follow individuals for up to 15 years. The reform we rely on for identification was implemented in 2001. In the estimation sample, we have two cohorts (1994-1995) that

Figure 17: Sample Selection

| Entry Cohort | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2004 | t= | | | | | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 |
| 2003 | t= | | | | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2002 | t= | | | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 2001 | t= | | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 2000 | t= | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1999 | t= | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1998 | t= | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1997 | t= | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 1996 | t= | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1995 | t= | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1994 | t= | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| | Year= | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |

were mostly out of college in 2001 and exposed only to the pre-reform aid system, five cohorts that were exposed to both aid systems starting at different enrollment years, and two cohorts (2001-2002) that were only exposed to the post-reform aid system.

## A.2 Variables

**High school variables:** After 9th grade – the end of compulsory schooling – most Swedish students enroll in an academic or vocational high school track. The two most common academic tracks are social sciences and natural sciences, where the latter has a stronger focus on mathematics. In our dataset, we observe all high school graduates, the year in which they graduate, the track, and their final GPA. We construct a dummy variable that is equal to one if the student graduates from the natural sciences high school track. We use this dummy as a proxy for mathematical skills, $K$, in our model. For our general ability variable, $A$, we construct a dummy for whether the final high school GPA is in the $90^{th}$ percentile of the student's cohort.

**University variables:** University programs in Sweden can require a minimum of 2 years, or 120 ECTS credits, to be accumulated completing relevant courses. 180 ECTS are necessary for acquiring a 3-year degree, 240 for a 4-year degree, and 300 for a 5-year degree. We group these programs into two categories: 3-year programs (which also include 2-year programs) and 4-year programs (which include both 4 and 5-year programs). We observe three types of students: those who directly enroll in a program, those who first enroll in courses and then enroll in a program, and those who enroll in courses and never switch to a program. About 80% of students enrolled in a university program, while the remaining 20% took courses without enrolling in a program. Students that we do not observe ever enrolling in a program are coded as enrolling in a 3-year program. Students who enroll in multiple programs in their career are considered as continuously enrolled in one program. If these multiple programs are of different length, we assign the student to either the longest program they complete or the program in which they have a majority of their credits (in the case that they don't graduate).

Students are allowed to attend courses outside the university program they are enrolled in and earn credits that can be counted towards their degree. For every student enrolled in university, we observe the courses they enroll in every semester, the courses they complete, and the number of ECTS credits required and completed. We also closely observe the subject of each course and the level of the program, if any, the course belongs to. Moreover, we observe the university or institution where the student attended each course. We group the courses into six broad fields:

1. Education
2. Humanities and Art
3. Social Sciences, Law, Business, Services
4. Math, Natural, Life and Computer Sciences (including Agriculture, Forestry, Veterinary)
5. Technical Sciences, Engineering
6. Health Sciences, Health and Social Care.

Swedish students tend to complete many courses both inside and outside their program, and often exit university with a higher number of credits than they need to graduate. In order to, at least in part, eliminate the extra credits, we identify the main broad field of study of the student and we keep only the courses in that field for our analysis. We also observe the year, field, and level of all graduations. When no courses are reported for one year in the middle of an education spell, we code it as college enrollment year with zero course credit production.

**Work and income:** From the Employment register, we observe employment status and total gross yearly income. Employment status follows the official definition and classifies those who have received compensation to work a minimum of one hour per week in the month of November as employed. As for every monetary measure, we deflate income to real year 2000 SEK. We also observe the months in which individuals are employed. We use all this information to define the work status choice variable $h_t$: If the individual is unemployed or employed with zero work months and zero yearly income, then $h_t = 0$. If the individual works only in the summer months (June, July, August) regardless of her employment status, then $h_t = 0.5$. If she is employed and works also in non summer months, then $h_t = 1$. Labor market experience,

$H_t$, is calculated by summing the history of work status for each individual up to time $t$. Labor market experience at start, $H_0$, is labor market experience up to the year before enrollment for those who enroll, and up to the year after graduating high school for those who do not enroll. We restrict $H_0$ to be smaller than or equal to 4, since the overwhelming majority of the population falls into these categories.

**Study aid:** For every year, we observe the total amount of study aid the student collects. Using information on their month-by-month income, which semesters they are enrolled in, and following the rules of the aid system as explained in Section 4, we calculate how much aid they are eligible for. We calculate both the grant and the loan amounts, defined in Section 5.1.2 as $\hat{b}$ and $\hat{\ell}$. Subtracting the grant amount from the total aid, we obtain the implied student loan amount they actually took up: $\tilde{\ell}$. We use $\tilde{\ell}$ to calculate cumulated student debt. The loan status choice variable, $\ell_t$, is defined based on both the actual and implied loan information:

$$
\begin{aligned}
&\text{if} \quad \hat{\ell}_t = 0 \quad \text{then} \quad \ell_t = 0;\\
&\text{if} \quad \tilde{\ell}_t \leq \frac{1}{4}\hat{\ell}_t \quad \text{then} \quad \ell_t = 0;\\
&\text{if} \quad \tilde{\ell}_t > \frac{1}{4}\hat{\ell}_t \quad \text{and} \quad \tilde{\ell}_t \leq \frac{3}{4}\hat{\ell}_t \quad \text{then} \quad \ell_t = 0.5;\\
&\text{if} \quad \tilde{\ell}_t > \frac{3}{4}\hat{\ell}_t \quad \text{then} \quad \ell_t = 1;
\end{aligned}
$$

For some students, the total aid is higher than that which they were eligible for – this is because there exist some extra grants and loans for study abroad. All of these students will appear as having taken up the full loan in our model. The maximum amount of aid by semester is adjusted to inflation and stays relatively constant over the relevant period, while the grant share is changed in 2001 as shown in Figure 18.

The aid is means-tested on a semester basis. There is a limit of student income above which the aid is reduced proportionally to income. This threshold is calculated every semester as a proportion of an inflation adjusted base amount, *prisbasbelopp*. The interest rate on the student debt is issued by the Department of Education of the Riksdagen every year. The interest rate is the unweighted average of the rates on all Treasury bills with 6 months maturity and five-year government bonds over 3 years (October-November three years later). The interest rate on student debt is 70% of this rate. In Table 6, we report the *prisbasbelopp* and the interest rate for the relevant years.

**Demographics and Parents:** For every high school graduate, we observe gender, geo-

Figure 18: Maximum Study Aid per Semester Over Time, 1991-2009

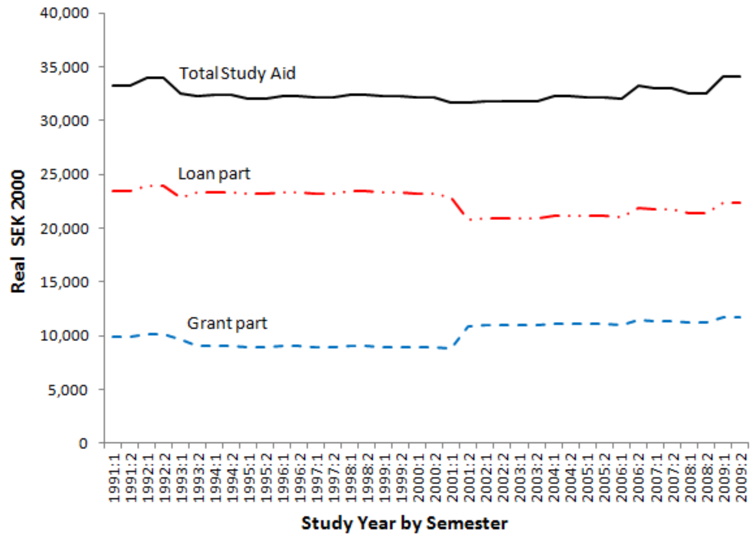



Table 6: Interest Rate and *Prisbasbelopp*, 1994-2009

| Year | Interest Rate | Prisbasbelopp |
|---|---|---|
| 1994 | .074 | 35,200 |
| 1995 | .066 | 35,700 |
| 1996 | .062 | 36,200 |
| 1997 | .060 | 36,300 |
| 1998 | .054 | 36,400 |
| 1999 | .041 | 36,400 |
| 2000 | .032 | 36,600 |
| 2001 | .031 | 36,900 |
| 2002 | .030 | 37,900 |
| 2003 | .032 | 38,600 |
| 2004 | .031 | 39,300 |
| 2005 | .028 | 39,400 |
| 2006 | .023 | 39,700 |
| 2007 | .021 | 40,300 |
| 2008 | .021 | 41,000 |
| 2009 | .025 | 42,800 |

graphical location, if they live with their parents, civil status, and if they have children. We also observe a number of parental characteristics: total gross yearly income, field and level of education, employment, civil status, as well as number of children. We also have information on the number of siblings, birth order, and the age distribution of siblings. We measure parental and family background variables in the year before college enrollment.

**Cost of Living:** We also merge information on the municipality of residence from the total population register (RTB). We use this geographic information to construct a Cost of Living Index (CLI) for each municipality in Sweden.[34] We group municipalities into three broad categories based on this index: Stockholm (CLI = 205) is the most expensive municipality to live in (more than twice as expensive as Prague). The second most expensive group of municipalities includes Karlstad, Västerås, Norrköping, Helsingborg, Malmö, Jonköping, Umeå, Göteborg, Örebro, and Uppsala. The rest of Sweden with CLI $\leq 160$ is in the third group.

## A.3 Unreported Data

Private higher institutions are not required to report detailed data on courses and academic credits, and most of them do not report this information regularly. Apart from the Stockholm School of Economics, most of these private schools are very small (with fewer than 1,000 students over our time period) and many of them do not exist for the entire sample period – either they closed or merged with a larger university. We drop students who do the bulk of their studies at these institutions. What follows is a list of these institutions:

1. Kungliga Konsthögskolan
2. Konstfack
3. Kungliga Musikhögskolan i Stockholm
4. Dramatiska institutet
5. Grafiska institutet
6. Danshögskolan
7. Operahögskolan i Stockholm
8. Teaterhögskolan i Stockholm
9. Hälsohögskolan i Värmland
10. Vårdhögskolan Falun
11. Hälsohögskolan Väst, Skövde
12. Bohusläns vårdhögskola
13. Vårdhögskolan i Eskilstuna
14. Vårdhögskolan Kristianstad
15. Vårdhögskolan Boden
16. Handelshögskolan i Stockholm (Stockholm School of Economics)

[34]The source for this index is http://www.expatistan.com/cost-of-living/country/sweden – Prague in Czech Republic is used as the reference city with CLI=100.

17. Stockholms Musikpedagogiska Institut
18. Gammelkroppa skogsskola
19. Ericastiftelsen
20. Hälsohögskolan i Stockholm
21. Hälsouniversitetet i Östergötland
22. Kalmar läns vrdhögskola
23. Vårdhögskolan i Halland
24. Vårdhögskolan Lund/Helsingborg
25. Hälsohögskolan i Umeå
26. Vårdhögskolan i Borås
27. Vårdhögskolan Gävle
28. Vårdhögskolan i Göteborg
29. Vårdhögskolan i Malmö
30. Vårdhögskolan i Sundsvall
31. Vårdhögskolan i Uppsala
32. Vårdhögskolan i Västerås
33. Vårdhögskolan i Vxjö
34. Vårdhögskolan i Örebro
35. Vårdhögskolan i Östersund
36. Örebro Teologiska Högskola
37. Johannelunds teologiska högskola
38. Teologiska Högskolan, Stockholm
39. Vårdhögskolan i Sundsvall/Örnsköldsvik
40. Svenska psykoanalytiska institutet
41. Göteborgs Psykoterapi Institut
42. Svenska psykoanalytiska sällskapet
43. Psykoterapisällskapet i Stockholm AB
44. Svenska institutet för kognitiv psykoterapi
45. Center för Cognitiv Psykoterapi o Utb. i Göteborg
46. Linnstadens Psykoterapi Institut
47. Svenska föreningen för Klinisk Hypnos
48. S:t Lukas
49. Stockholms akademi för psykoterapiutbildning
50. Beckmans Designhgskola

# B Solution and Estimation of the Model

In the following paragraphs we detail our implementation of the CCP estimator with a sequential EM algorithm from Arcidiacono and Miller (2011) to estimate our model parameters. Arcidiacono and Miller (2011) show that this algorithm converges to a fixed point and is computationally feasible for many problems with the finite time dependence property.

The estimation problem we need to solve is the following:

$$(\hat{\theta}, \hat{\pi}) = arg \max_{\theta,\pi} \sum_{i=1}^{N} \ln \left[ \sum_{m=1}^{m} \pi(m \mid X_{i0}) \prod_{t=1}^{T} L_t(d_{it}, X_{it+1} \mid X_{it}, m; \theta) \right]. \tag{B.1}$$

Given values for $\theta^{(n)}$ and $\pi^{(n)}$, and of the conditional choice probability of the terminal state $p^{(n)}$, the $(n+1)$ iteration of the the EM-CCP algorithm is as follows: In the expectation step, we update the conditional probabilities of individual $i$ being unobserved type $m$ given the data and the model parameters:

$$q^{(n+1)}(m \mid d_i, X_i) = \frac{\pi^{(n)}(m \mid X_{i0}) \prod_t L_t(d_{it}, X_{it+1} \mid X_{it}, m, p^{(n)}; \theta^{(n)})}{\sum_{m'} \pi^{(n)}(m' \mid X_{i0}) \prod_t L_t(d_{it}, X_{it+1} \mid X_{it}, m', p^{(n)}; \theta^{(n)})}. \tag{B.2}$$

The conditional probability of being in each unobserved state is linked to the probability of being in state $m$ given the data at the first observed time period (given time invariability). We update the population type probabilities $\pi(m \mid X_{i0})$ as:

$$\pi^{(n+1)}(m \mid X_0) = \frac{\sum_i q^{(n+1)}(m \mid d_i, X_i) \mathbf{1}(X_{i0} = X_0)}{\sum_i \mathbf{1}(X_{i0} = X_0)}. \tag{B.3}$$

The EM algorithm is notoriously very slow to converge, and a good initial guess of the mixture distribution and the likelihood can make a large difference. We run the CCP estimation without unobserved states to get a starting value for the likelihood. To get good starting values for the $\pi$'s we run the first stage of a two-stage estimation as described in section 4.3 of Arcidiacono and Ellickson (2011), where the conditional probabilities of the unobserved states are estimated in a first stage, allowing the CCP's to be completely flexible. We run this algorithm for 20 iterations and then we feed the resulting values into our EM algorithm.

In the maximization step, we take $q^{(n+1)}(m \mid d_i, X_i)$ as given and obtain $\theta^{(n+1)}$:

$$\theta^{(n+1)} = arg \max_{\theta} \sum_{m=1}^{M} \sum_{i=1}^{N} \sum_{t=1}^{T} q^{(n+1)} \left(m \mid d_i, X_i\right) \left( \ln \left[ L_t \left( d_{it}, X_{it+1} \mid X_{it}, m, p^{(n)}; \theta^{(n)} \right) \right] \right). \tag{B.4}$$

When the types are treated as observed, additive separability can be reintroduced, and the maximization step can be divided in two parts: First the law of motions of the states $G_t$, $E_t$, and $Y_t$ are estimated given the type distribution estimated in the expectation step. At this point we can estimate the preference parameters. We first calculate the conditional value functions for every possible choice as a function of the value of the terminal choice $d^0$ and the CCP of choosing $d^0$:

$$v_t^j(X_t) = U^j(X_t) + \beta \mathop{\mathbb{E}}_{X_{t+1}} \left( v_{t+1}^0(X_{t+1}) - \ln \left[ p_{t+1} \left( d^0 \mid X_{t+1} \right) \right] \right) + \beta \xi \tag{B.5}$$

where $\xi$ is the Euler constant ($\xi = 0.57722$). We get the CCP of the terminal choice $d^0$ by running a flexible logit over the entire state, and we calculate the future value functions by simulating the future income and debt repayment of the student given their choice today and given the inter-temporal elasticity of substitution. We then retrieve the parameters of the payoff function by maximizing the likelihood of the school-work-loan choice given the state and the future choice-specific value functions. We estimate the intertemporal elasticity of substitution parameter $\lambda$ by iterating between the two steps of simulating the future value functions and maximizing the likelihood. Inside the same loop we also update the CCP of the terminal choice $d^0$ at each step by running the flexible logit of the predicted probability of the terminal choice obtained from the model over the state, and recalculating the future value functions according to equation B.5. The last step of the CCP estimation is to retrieve the parameters $\zeta$ for the choice of enrolling in college at $t = 0$. We calculate the ex-ante expected value functions of not enrolling and of enrolling in a 2-3 years or 4-5 years program using the choice probabilities and value functions from the step above, and then we maximize the likelihood. Finally, we update the CCPs of the terminal choice augmented with the unobserved state $m$ from the likelihood:

$$p^{(n+1)}(d_t^0 \mid X_t, m) = L_t \left( d_t^0 \mid X_t, m; p^{(n)}, \theta^{(n+1)} \right). \tag{B.6}$$

## B.1 Simulation Algorithm

The state variables of our model are $X_t = (A, K, S_0, D_t, G_t, E_t, H_t, h_{t-1}, \ell_{t-1}, t)$. We simulate the model separately for the invariant states and choices $(A, K, S_0)$ and types $m$, that is we simulate the model $2 \times 2 \times 2 \times M$ times. For every combination of $(A, K, m)$ we derive the enrollment probabilities. We impose that at $t = 11$ everyone is in full-time work and not enrolled. We allow the grids for cumulated course credits and experience to comprise all possible states while we simplify the cumulated loan grid to take values between zero and the maximum available loan amount (maxloan) cumulated over seven years, with linear steps equal to one eight of the maximum loan amount available per year. This means that the grid for $G$ has 31 points ($\{0, 1, \cdots, 30\}$), the grid for $H$ has 31 points ($\{0, .5, 1, \cdots, 15\}$), and the grid for $D$ has 57 points ($\{0, maxloan * .125, maxloan * .25, \cdots, maxloan * 7\}$. The past choices $h_{t-1}, \ell_{t-1}$ have 3 grid points each, while graduation $E$ is a binary variable. This results in grid with $N_{grid} = 57 \times 31 \times 2 \times 31 \times 3 \times 3 = 1,304,046$ grid-points for every combination of initial conditions.

We start the simulation by calculating the wages and aid for every possible state and choice $j = 0, \ldots, 9$. We solve for the probabilities of achieving $g_t = 0, \ldots, 7$ course credits for every period conditional on the choices. Then, we solve for the graduation probabilities given credits and choices. We use the state probabilities and the parameters from the CCP estimation to calculate the value functions for every choice: we start from the last period, when everyone is forced out of college and the value functions are deterministic. We continue by backward induction using both the state transition probabilities and the conditional choice probabilities from the CCP estimation. We then use the choice-specific value functions obtained to calculate the CCPs of choosing $j = 0, \ldots, 9$. Finally, we simulate different sets of policies in the following way: we start with a cohort of high school graduates at $t = 1$, all starting with previous work status $h_{-1} = 0$ , with zero cumulated course credits, $G_0 = 0$, zero cumulated student loan, $D_0 = 0$ and $\ell_{-1} = 0$, but different initial abilities and skills, $A \in \{0, 1\}$ and $K \in \{0, 1\}$, and work experience, $\tilde{H}_0 \in \{0, \cdots, 4\}$. Initial conditions are distributed to mirror our sample (unless otherwise specified) and the estimated type distribution. The initial conditions distribution we use is shown in table 7.

The distribution over enrollment duration $S_0$ is calculated within the simulation using the value functions simulated for both $S_0 = 3$ and $S_0 = 4$. We then simulate the choices and state progression of this cohort using the course credit production probabilities and CCPs for each

Table 7: Distribution over Initial Conditions

| $H_0$ | $A=0$ $K=0$ | $A=0$ $K=1$ | $A=1$ $K=0$ | $A=1$ $K=1$ | |
|---|---|---|---|---|---|
| 0 | .0337 | .0268 | .0099 | .0134 | .0838 |
| .5 | .0432 | .0299 | .0125 | .0141 | .0997 |
| 1 | .0665 | .0383 | .0172 | .0168 | .1388 |
| 1.5 | .0812 | .0431 | .0214 | .0182 | .1639 |
| 2 | .0912 | .0352 | .0179 | .0116 | .1559 |
| 2.5 | .0805 | .0259 | .0126 | .0073 | .1263 |
| 3 | .0714 | .0177 | .0087 | .0035 | .1013 |
| 3.5 | .0535 | .0113 | .0053 | .0017 | .0718 |
| 4 | .0434 | .0091 | .0046 | .0014 | .0585 |
| | .5646 | .2373 | .1100 | .0880 | 1 |

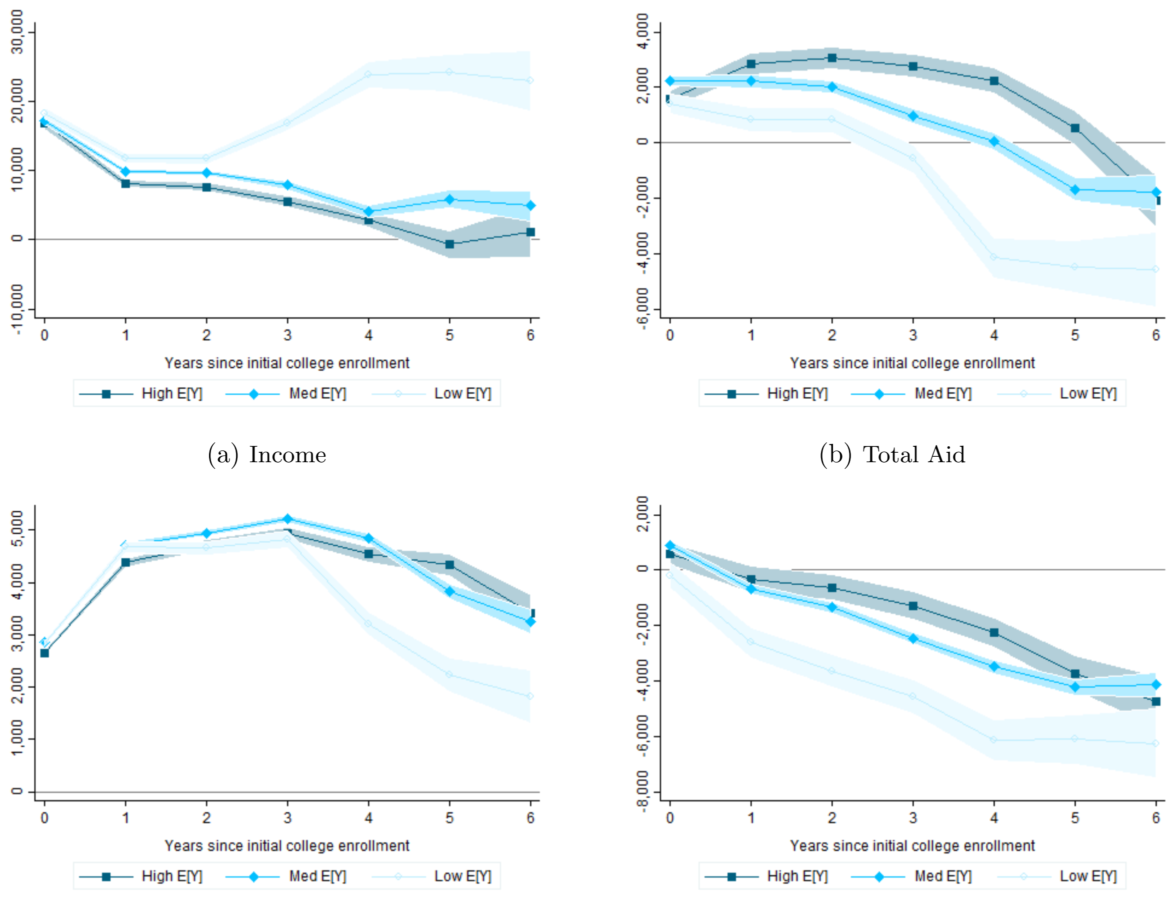
study aid policy.

In all simulations we use the institutional details from 2001: the interest rate is set to 3.1% and the *prisbasbelopp* to 36,900 SEK.

# C Additional Figures

## C.1 Reduced Form Estimates

Figure 19: Reduced Form Estimates of Reform Impact: Student Income and Aid




(a) Income

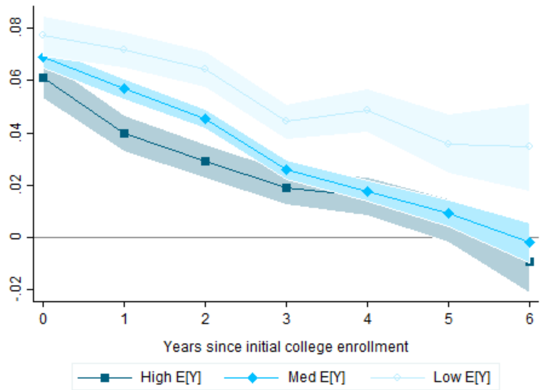
(b) Total Aid

(c) Grant

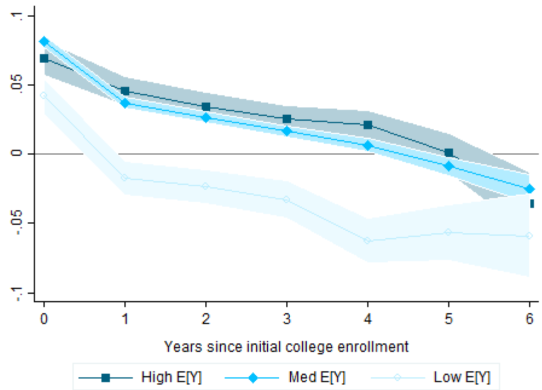
(d) Loan

The Figure displays reduced form estimates of the total effect of the reform on total student aid and the three components of student budget sets: labor income, grant, and loan. Reduced form estimates are presented separately for each year since initial enrollment, $t = 0, 1, ..., 6$. All estimates are presented separately by whether expected income is more than one standard deviation below the average (Low $\mathbb{E}[Y]$), more than one standard deviation above the average (High $\mathbb{E}[Y]$), or in between (Med $\mathbb{E}[Y]$). Expected incomes are based on the predicted values from a regression of log-income on a fully saturated model of initial conditions $(A, K, H_0, S_0)$ and field of initial enrollment. The estimates are robust to adding year controls. The shaded areas display the 95% confidence intervals.

Figure 20: Reduced Form Estimates of Reform Impact: Employment Status and Loan Take-up




(a) Employment Status



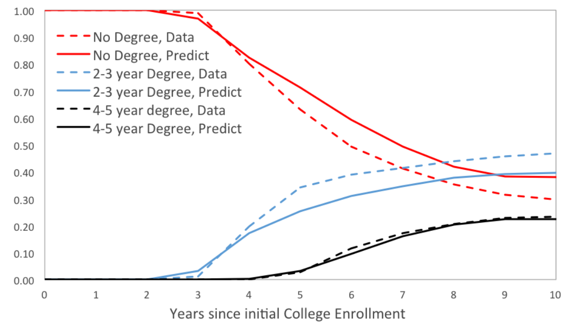

(b) Loan Take-up

The Figure displays reduced form estimates of the total effect of the reform on student choices: employment status and loan take-up. Reduced form estimates are presented separately for each year since initial enrollment, $t = 0, 1, ..., 6$. All estimates are presented separately by whether expected income is more than one standard deviation below the average (Low $\mathbb{E}[Y]$), more than one standard deviation above the average (High $\mathbb{E}[Y]$), or in between (Med $\mathbb{E}[Y]$). Expected incomes are based on the predicted values from a regression of log-income on a fully saturated model of initial conditions $(A, K, H_0, S_0)$ and field of initial enrollment. The estimates are robust to adding year controls. The shaded areas display the 95% confidence intervals.

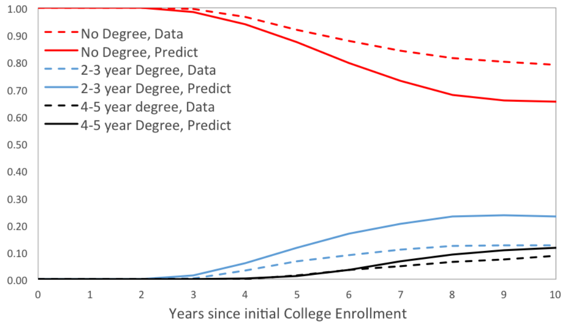
## C.2 Model Fit

Detailed model fit tables can be found in the `Online Appendix` .

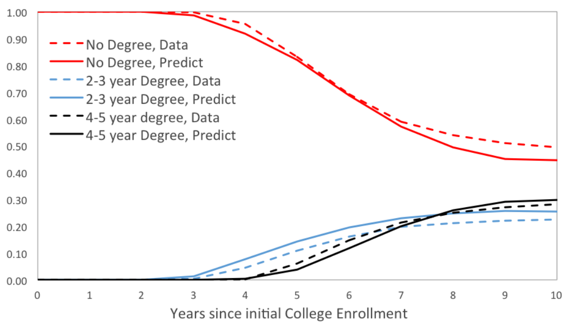
Figure 21: Model Fit of Highest Acquired Degree, by Field



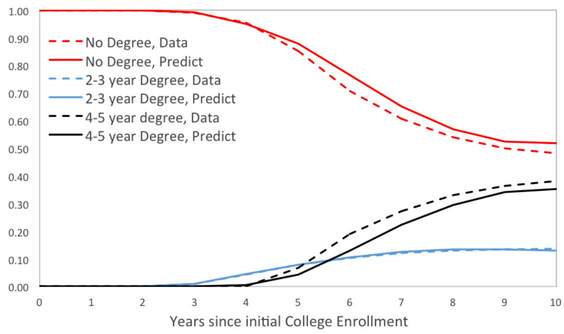

(a) Education



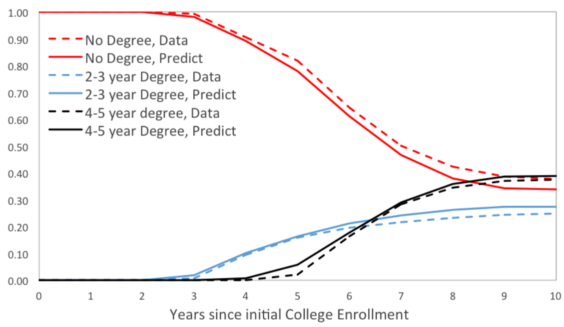

(b) Humanities and Arts



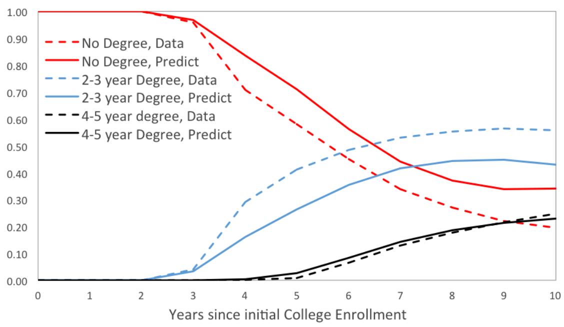

(c) Social Sciences, Law, Business, Services




(d) Math, Natural, Life, and Computer Sciences

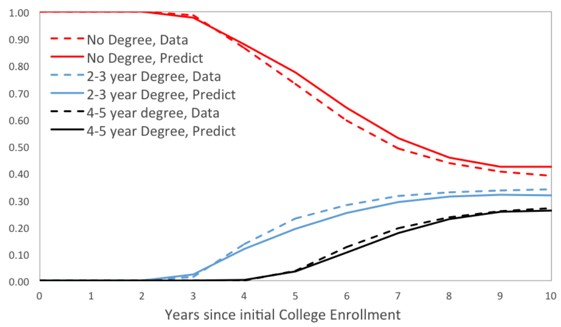



(e) Technical Sciences, Engineering

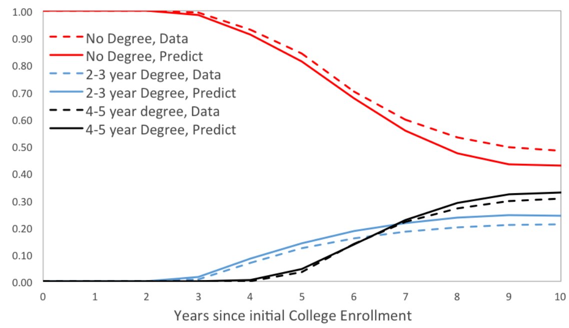



(f) Health Sciences, Health and Social Care

Figure 22: Model Fit of Highest Acquired Degree, by Gender

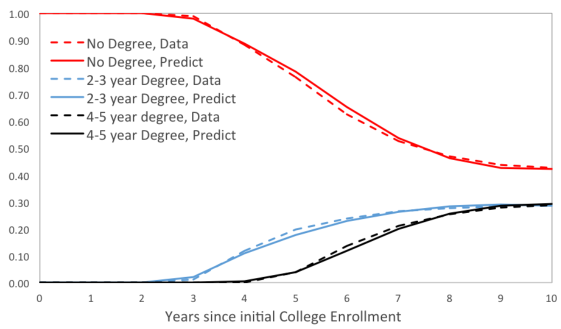



(a) Female

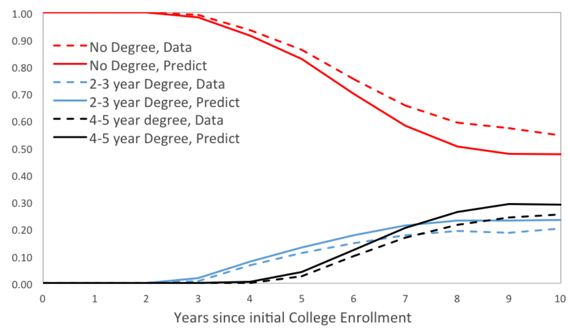



(b) Male

Figure 23: Model Fit of Highest Acquired Degree, by Coresidence Status

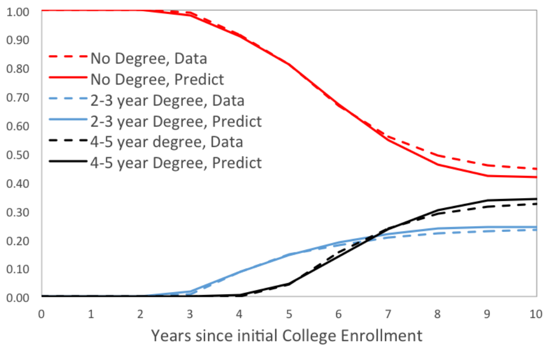



(a) Non Coresiding

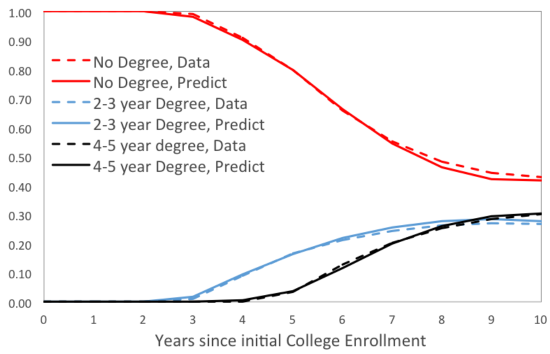



(b) Coresiding

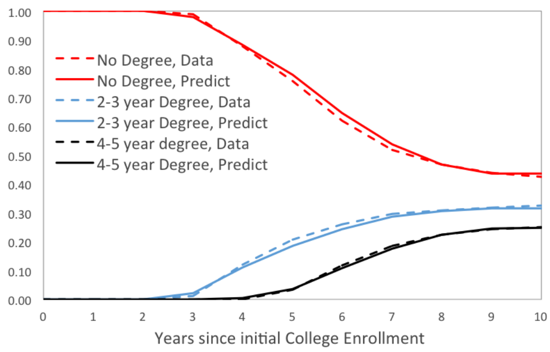
Figure 24: Model Fit of Highest Acquired Degree, by Cost of Living




(a) Stockholm metropolitan area, CLI$\geq$ 200



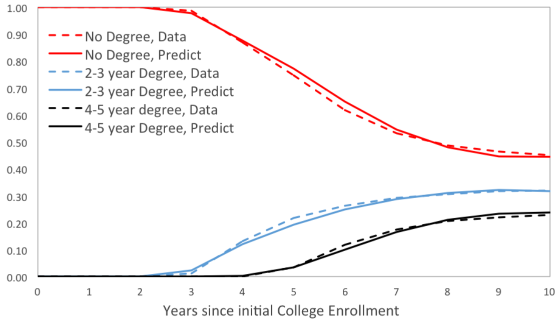

(b) Cities with 160 $\leq$CLI$<$ 200



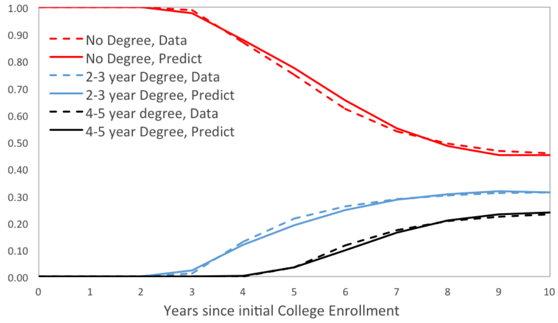

(c) Rest of Sweden, CLI$<$ 160

We divide Sweden in three geographic areas: the Stockholm metropolitan area, where cost of living is highest (CLI$>$ 200), municipalities with larger cities with CLI between 200 and 160 (Karlstad, Västerås, Norrköping, Helsingborg, Malmö, Jonköping, Umeå, Göteborg, Örebro, and Uppsala), and the rest of Sweden with CLI$<$ 160.

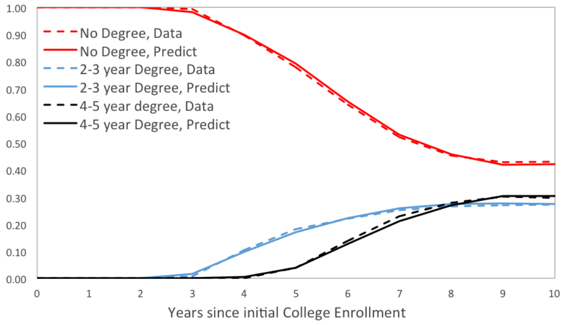
Figure 25: Model Fit of Highest Acquired Degree, by Parental Education



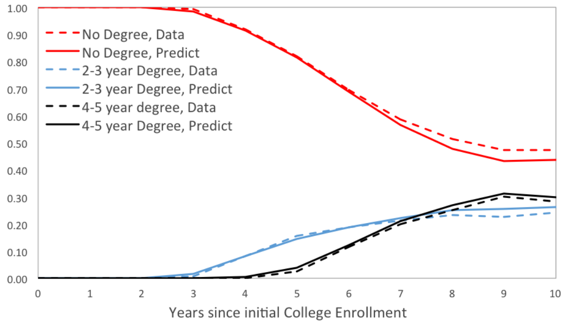

(a) Father: Basic Schooling or High School



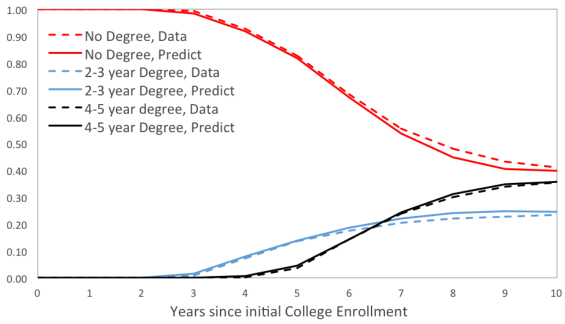

(b) Mother: Basic Schooling or High School



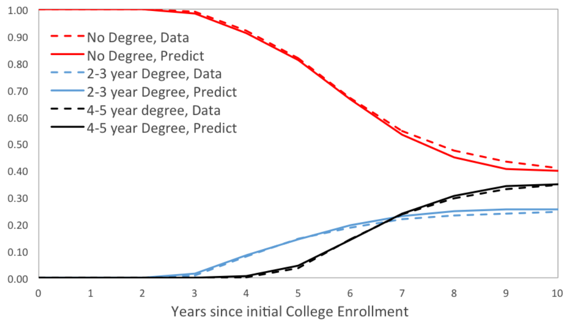

(c) Father: Higher Education $\leq 2$ years



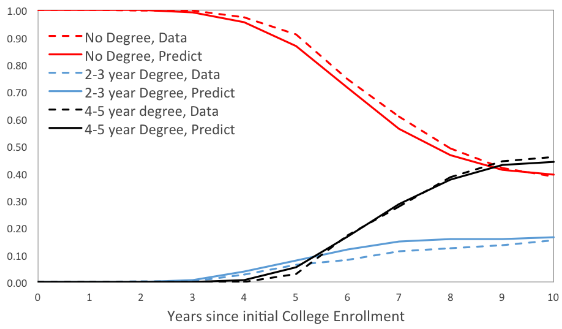

(d) Mother: Higher Education $\leq 2$ years



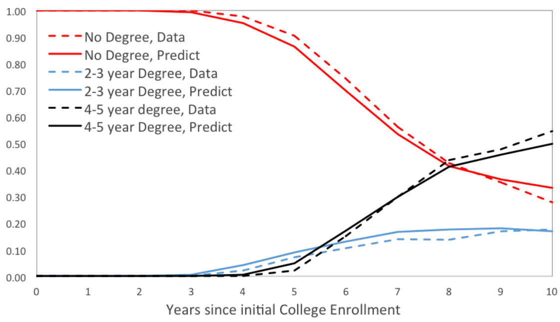

(e) Father: Higher Education $\geq 3$ years




(f) Mother: Higher Education $\geq 3$ years

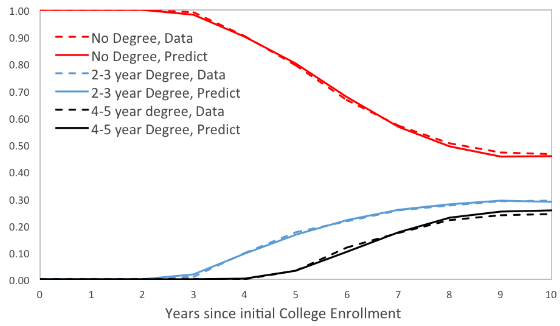



(g) Father: Postgraduate Education

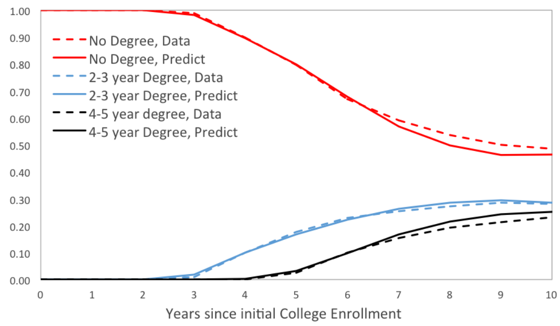



(h) Mother: Postgraduate Education

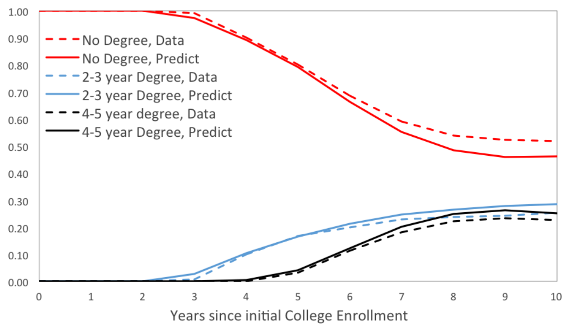
Figure 26: Model Fit of Highest Acquired Degree, by Parental Income



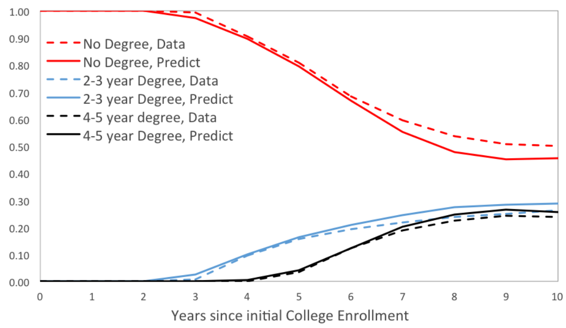

(a) Father Income < P10




(b) Mother Income < P10

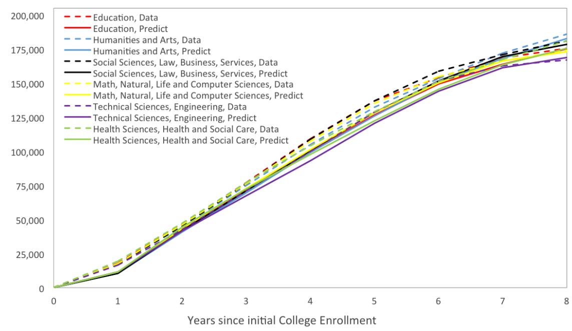



(c) Father Income > P90

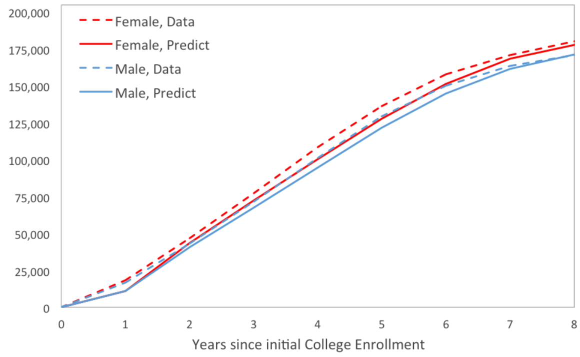



(d) Mother Income > P90

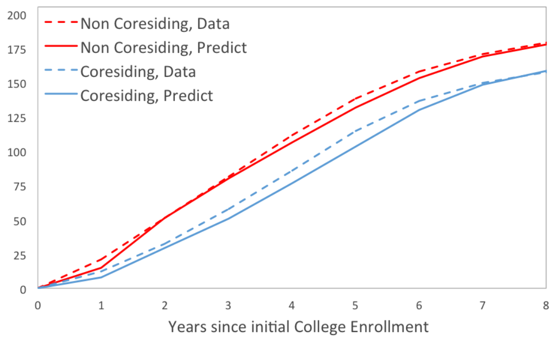
Figure 27: Model Fit of Student Debt



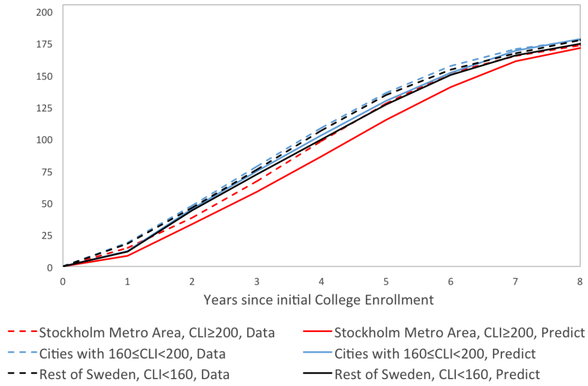

(a) Student Debt, by Field



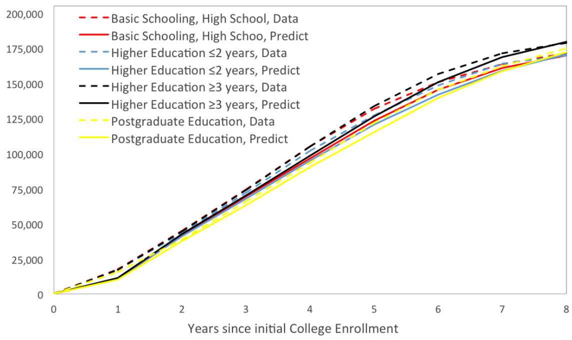

(b) Student Debt, by Gender



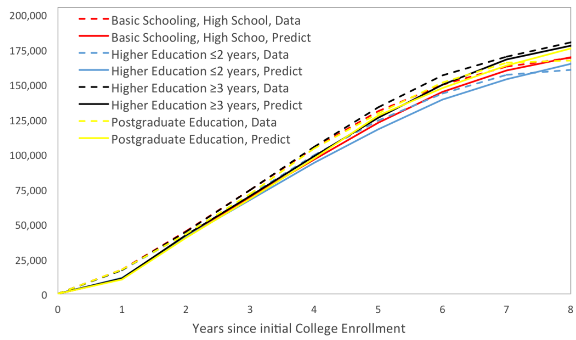

(c) Student Debt, by Coresidence Status



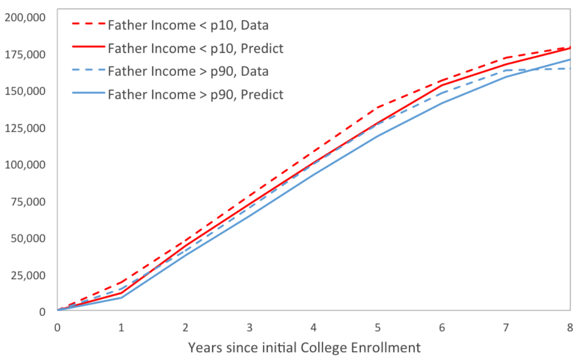

(d) Student Debt, by Cost of Living



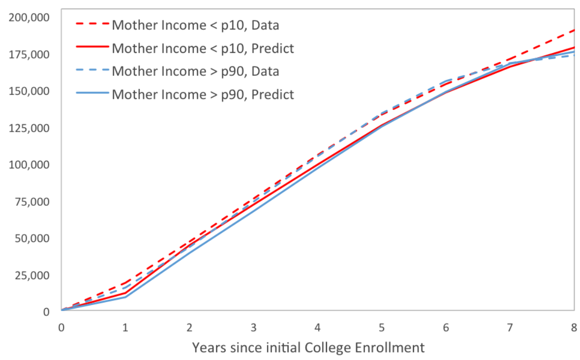

(e) Student Debt, by Father Education




(f) Student Debt, by Mother Education

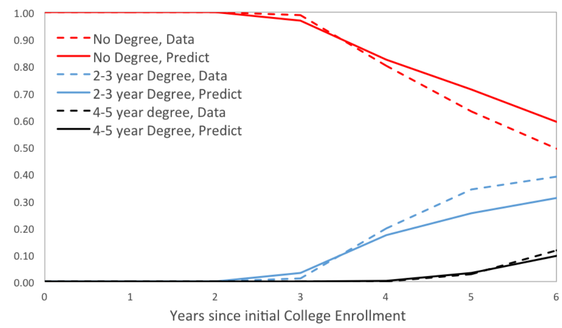



(g) Student Debt, by Father Income

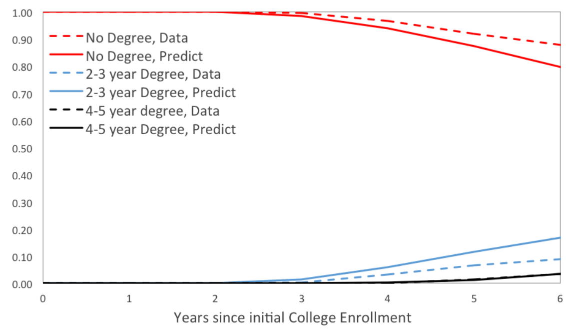



(h) Student Debt, by Mother Income

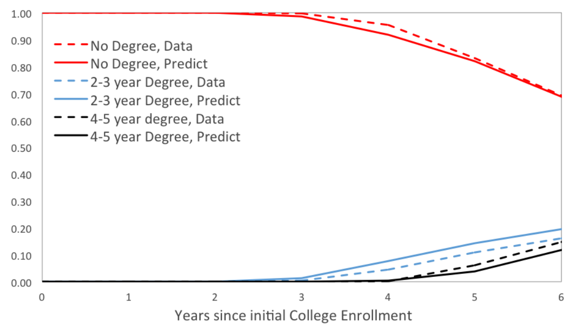
Figure 28: Model Fit of Highest Acquired Degree, Out of Sample, by Field



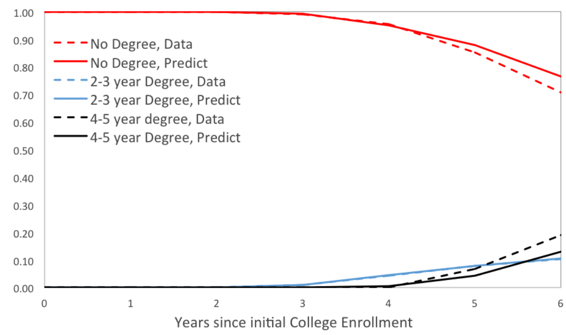

(a) Education



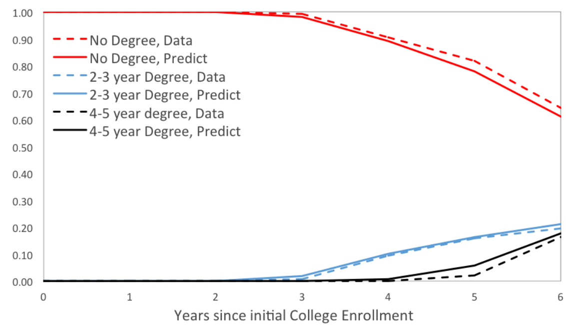

(b) Humanities and Arts



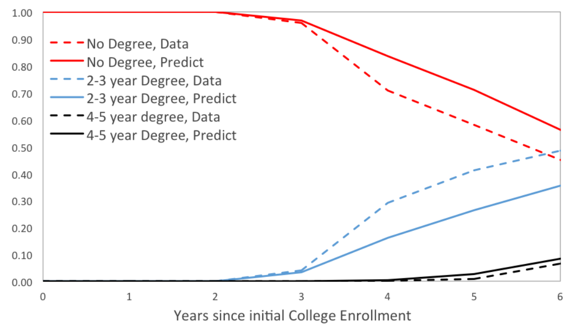

(c) Social Sciences, Law, Business, Services




(d) Math, Natural, Life, and Computer Sciences

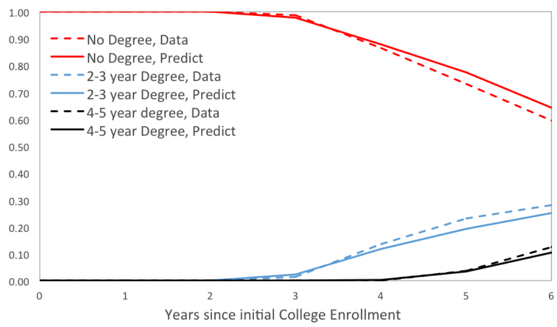



(e) Technical Sciences, Engineering

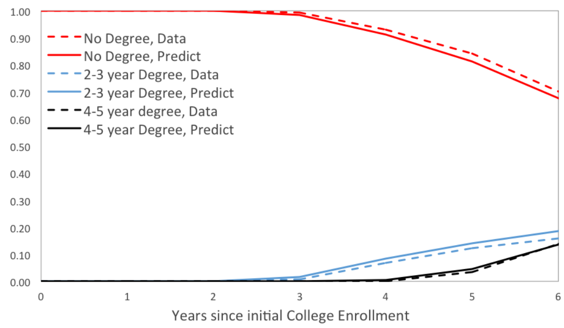



(f) Health Sciences, Health and Social Care

Figure 29: Model Fit of Highest Acquired Degree, Out of Sample, by Gender

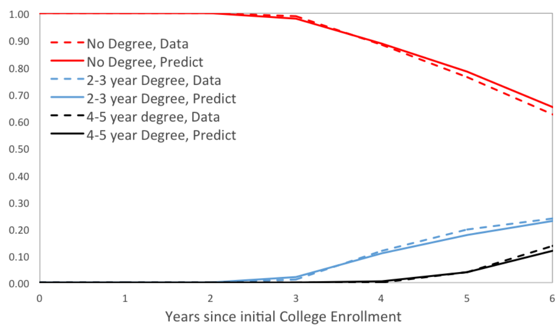



(a) Female

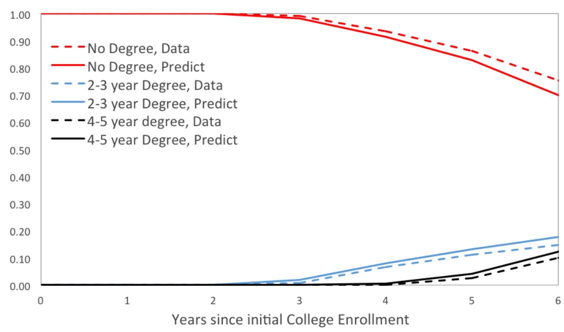



(b) Male

Figure 30: Model Fit of Highest Acquired Degree, Out of Sample, by Coresidence Status

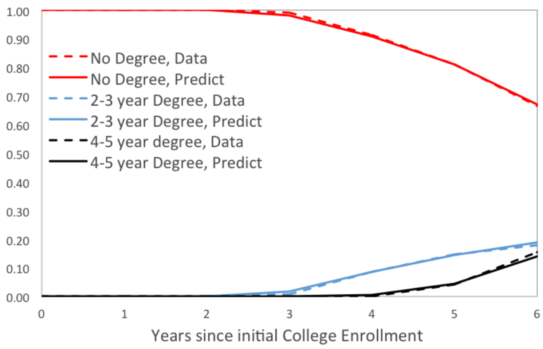



(a) Non Coresiding

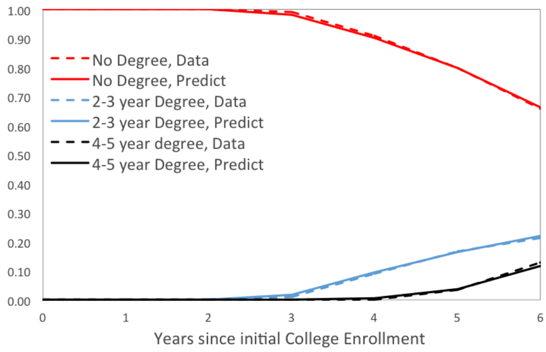



(b) Coresiding

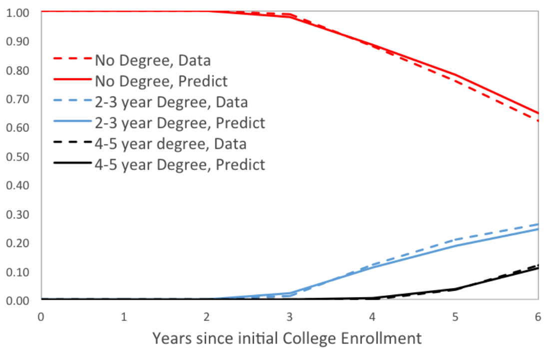
Figure 31: Model Fit of Highest Acquired Degree, Out of Sample, by Cost of Living




(a) Stockholm metropolitan area, CLI≥ 200



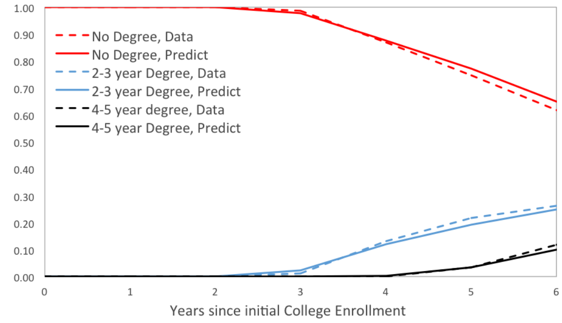

(b) Cities with 160 ≤CLI< 200



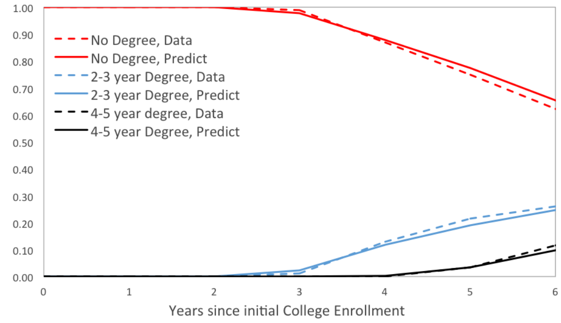

(c) Rest of Sweden, CLI< 160

We divide Sweden in three geographic areas: the Stockholm metropolitan area, where cost of living is highest (CLI> 200), municipalities with larger cities with CLI between 200 and 160 (Karlstad, Västerås, Norrköping, Helsingborg, Malmö, Jonköping, Umeå, Göteborg, Örebro, and Uppsala), and the rest of Sweden with CLI< 160.

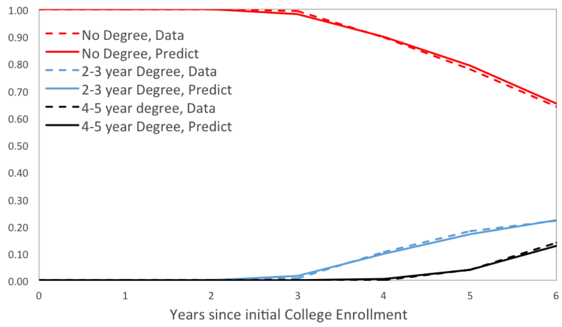
Figure 32: Model Fit of Highest Acquired Degree, Out of Sample, by Parental Education



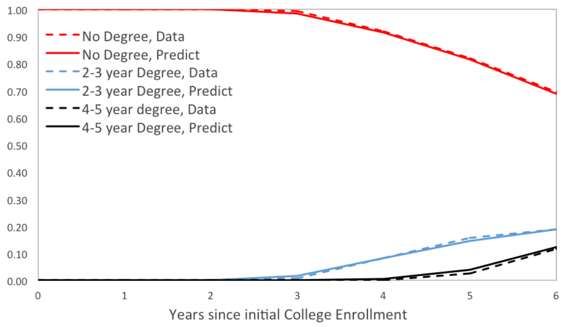

(a) Father: Basic Schooling or High School



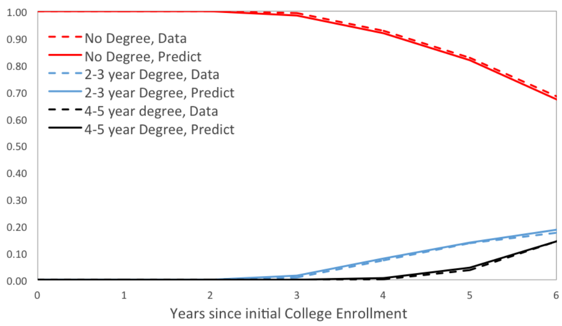

(b) Mother: Basic Schooling or High School



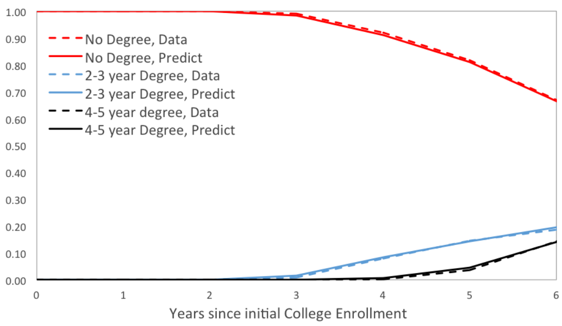

(c) Father: Higher Education $\leq 2$ years



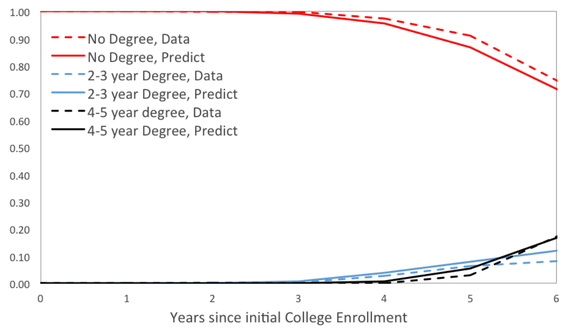

(d) Mother: Higher Education $\leq 2$ years



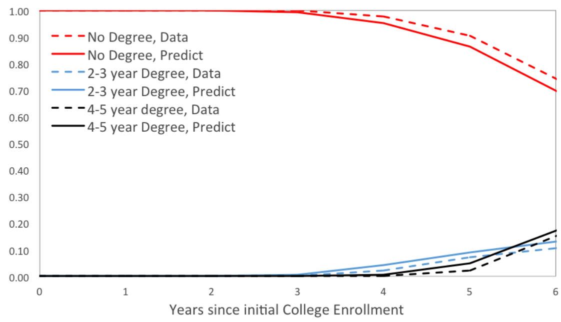

(e) Father: Higher Education $\geq 3$ years




(f) Mother: Higher Education $\geq 3$ years

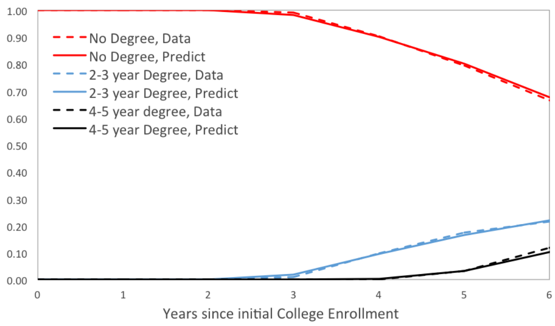



(g) Father: Postgraduate Education

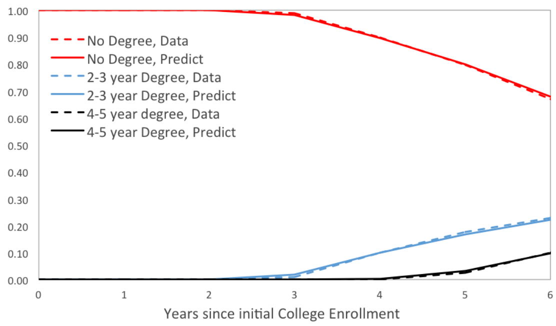



(h) Mother: Postgraduate Education

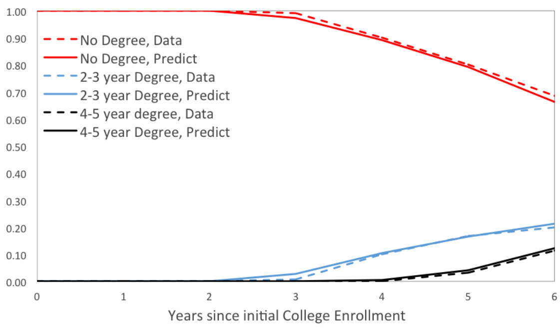
Figure 33: Model Fit of Highest Acquired Degree, Out of Sample, by Parental Income



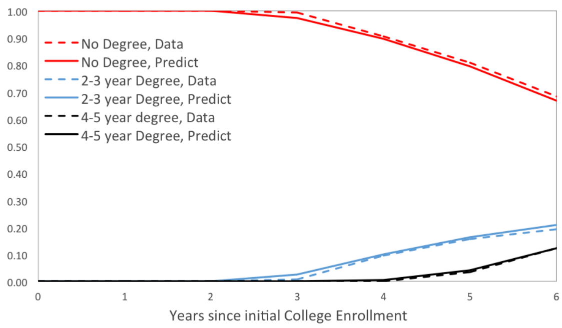

(a) Father Income < P10




(b) Mother Income < P10

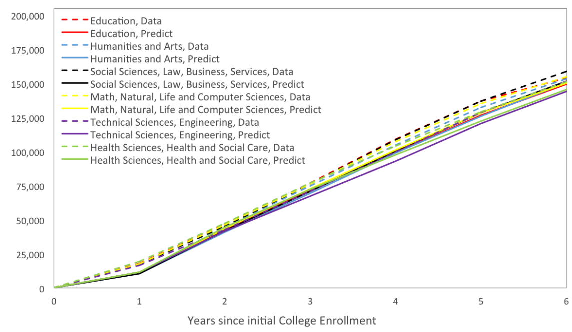



(c) Father Income > P90

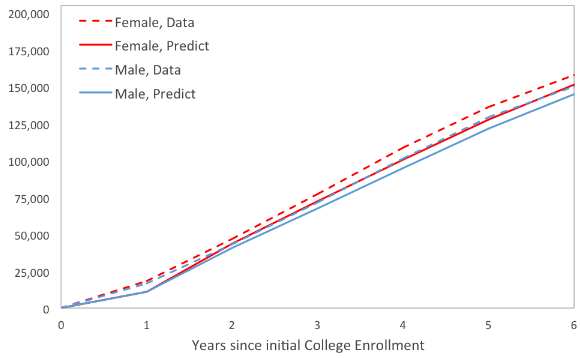



(d) Mother Income > P90

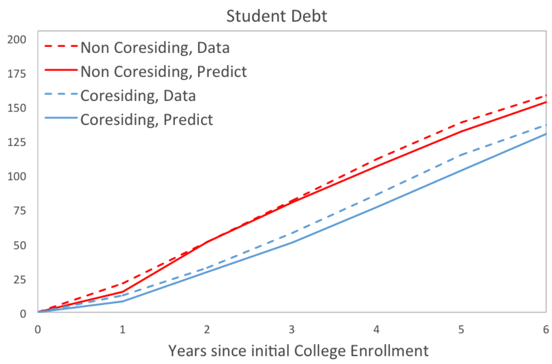
## Figure 34: Model Fit of Student Debt, Out of Sample



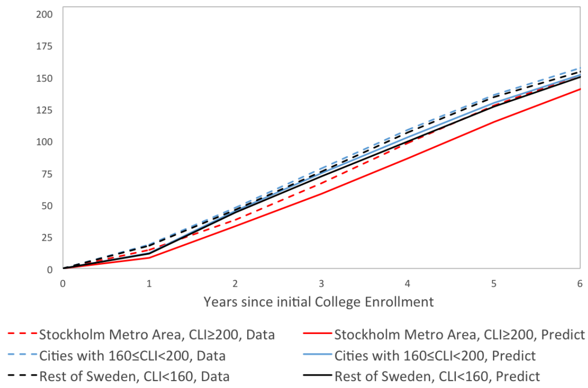

(a) Student Debt, by Field



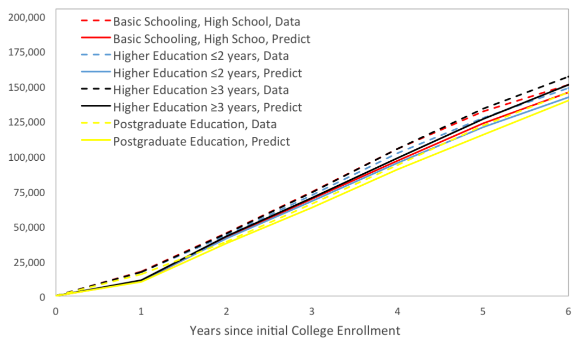

(b) Student Debt, by Gender



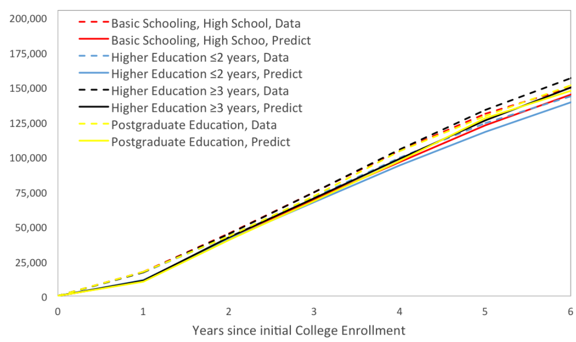

(c) Student Debt, by Coresidence Status



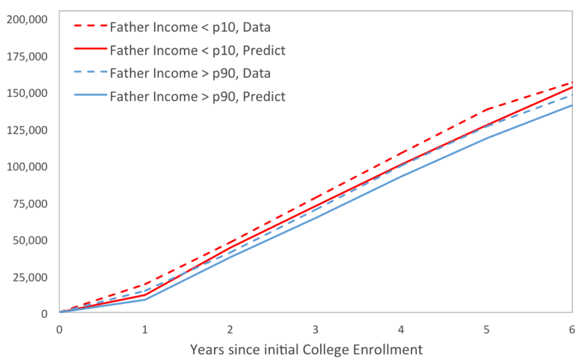

(d) Student Debt, by Cost of Living



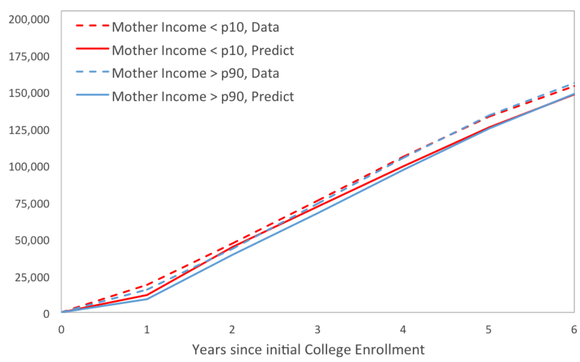

(e) Student Debt, by Father Education




(f) Student Debt, by Mother Education




(g) Student Debt, by Father Income




(h) Student Debt, by Mother Income

# D Tables

Table 8: Descriptives of Additional Heterogeneity, at University Entry

| | | | | Graduates | |
|---|---|---|---|---|---|
| **Individual Characteristics** | Everyone | Enrolled | Dropouts | 2-3 years | 4-5+ years |
| Female | 0.494 | 0.549 | 0.498 | 0.668 | 0.522 |
| Co-residing with Parents | 0.619 | 0.555 | 0.575 | 0.522 | 0.557 |
| **Field of enrollment** | | | | | |
| Education | | 0.142 | 0.097 | 0.219 | 0.131 |
| Humanities and Arts | | 0.098 | 0.184 | 0.047 | 0.026 |
| Social Sciences, Law, Business | | 0.295 | 0.339 | 0.243 | 0.285 |
| Math, Natural, Life, IT Sciences | | 0.095 | 0.108 | 0.049 | 0.120 |
| Technical Sciences, Engineering | | 0.261 | 0.229 | 0.215 | 0.350 |
| Health Sciences, Health and Social Care | | 0.109 | 0.043 | 0.227 | 0.088 |
| **Cost of Living Index (CLI)** | | | | | |
| Stockholm Metro Area, $CLI > 200$ | 0.171 | 0.167 | 0.178 | 0.137 | 0.179 |
| Cities with $160 < CLI < 200$ | 0.163 | 0.205 | 0.202 | 0.202 | 0.213 |
| Rest of Sweden, $CLI < 160$ | 0.666 | 0.628 | 0.619 | 0.661 | 0.608 |
| **Mother's Income** | | | | | |
| Mother's income below 10p | .100 | .078 | .087 | .075 | .066 |
| Mother's income above 90p | .099 | .167 | .169 | .144 | .186 |
| **Father's Income** | | | | | |
| Father's income below 10p | .101 | .080 | .088 | .079 | .068 |
| Father's income above 90p | .095 | .173 | .170 | .146 | .203 |
| **Mother's Education** | | | | | |
| Basic Schooling, High School | .700 | .551 | .581 | .608 | .453 |
| Higher Education $\leq$2 years | .023 | .032 | .034 | .027 | .033 |
| Higher Education $\geq$3 years | .272 | .409 | .379 | .360 | .501 |
| Postgraduate Education | .004 | .008 | .006 | .004 | .013 |
| **Father's Education** | | | | | |
| Basic Schooling, High School | .732 | .586 | .612 | .652 | .484 |
| Higher Education $\leq$2 years | .051 | .067 | .067 | .064 | .068 |
| Higher Education $\geq$3 years | .201 | .317 | .295 | .265 | .399 |
| Postgraduate Education | .015 | .030 | .025 | .019 | .048 |
| **N individuals** | 698,227 | 287,649 | 120,122 | 81,983 | 85,589 |
| **Fraction of Sample** | 1.00 | 0.41 | 0.17 | 0.12 | 0.12 |
| **Fraction of Students** | | | 0.42 | 0.28 | 0.30 |

Sample averages, standard deviations in parenthesis. One year of full-time studies corresponds to 60 ECTS. All amounts are in real SEK 2000. The exchange rate ultimo December 2000 was 9.3955 SEK/USD and 8.8263 SEK/EUR.

## D.1 Estimation Parameters

Table 9: Estimates of Model Parameters, 1 type

| | | $S_0 = 3$ | $S_0 = 4$ |
|---|---|---|---|
| | | $w_t$ | |
| | $\alpha_0$ | 11.7054 | |
| graduate | $\alpha_1^s$ | .1744 | .2653 |
| course credits | $\alpha_2^s$ | .0152 | .0141 |
| first enrollment period | $\alpha_3$ | .0556 | |
| student | $\alpha_4$ | -.9384 | |
| summer work | $\alpha_5$ | -1.3253 | |
| experience profile, student | $\alpha_6$ | .1077 | |
| experience profile, dropout | $\alpha_7$ | .0438 | |
| experience profile, graduate | $\alpha_8^s$ | -.0377 | .0321 |
| variance | | .9078 | |
| | | $g_t^*$ | |
| (high school GPA $\geq P90$) | $\gamma_1^s$ | .0905 | .3102 |
| high school science track | $\gamma_2^s$ | .0092 | .0655 |
| graduate | $\gamma_3^s$ | -1.0685 | -1.8893 |
| course credits | $\gamma_4^s$ | .0654 | .0550 |
| time since initial enrollment | $\gamma_5^s$ | -.2728 | -.2604 |
| first enrollment period | $\gamma_6^s$ | -.5946 | -.71384 |
| summer work | $\gamma_7^s$ | .4143 | .2982 |
| year-round work | $\gamma_8^s$ | -.2582 | -.3633 |
| partial loan | $\gamma_9^s$ | .7127 | .6145 |
| full loan | $\gamma_{10}^s$ | .7852 | .7235 |
| | | $e_t^*$ | |
| | $\eta_0^s$ | -8.7742 | -15.0083 |
| (course credits $\geq$ 12) | $\eta_1^s$ | 1.3002 | -.3092 |
| (course credits $\geq$ 15) | $\eta_2^s$ | .5918 | -.3567 |
| (course credits $\geq$ 18) | $\eta_3^s$ | 2.2119 | .7403 |
| (course credits $\geq$ 21) | $\eta_4^s$ | .2539 | 1.2140 |
| (course credits $\geq$ 24) | $\eta_5^s$ | .0764 | 1.5859 |
| (course credits $\geq$ 27) | $\eta_6^s$ | -.5388 | .5593 |
| (course credits $\geq$ 30) | $\eta_7^s$ | -.4300 | -.0659 |
| time since initial enrollment | $\eta_8^s$ | 1.2629 | 2.4971 |
| time since initial enrollment$^2$ | $\eta_9^s$ | -.0616 | -.1152 |
| time $\times$ (course credits $\geq$ 12) | $\eta_{10}^s$ | .0336 | .1124 |
| time $\times$ (course credits $\geq$ 15) | $\eta_{11}^s$ | -.0251 | .0034 |
| time $\times$ (course credits $\geq$ 18) | $\eta_{12}^s$ | -.0800 | -.0510 |
| time $\times$ (course credits $\geq$ 21) | $\eta_{13}^s$ | .0053 | -.0604 |
| time $\times$ (course credits $\geq$ 24) | $\eta_{14}^s$ | -.0064 | -.0700 |
| time $\times$ (course credits $\geq$ 27) | $\eta_{15}^s$ | .0556 | .0023 |
| time $\times$ (course credits $\geq$ 30) | $\eta_{16}^s$ | .0607 | .0715 |

Coefficients from the wage equation (eq. 15), course credits production (eq. 12), and graduation probability (eq. 14). Superscript indicate the choices: $j \in \{0, 9\}$, $s \in \{3, 4\}$.

Table 10: Estimates of Model Parameters, 1 type – cont.

| | | $S_0 = 3$ | $S_0 = 4$ |
|---|---|---|---|
| | | $P(d_t^j = 1)$ | |
| | $\nu_0$ | .3606 | |
| time since initial enrollment | $\nu_1^{j=1,s}$ | .0253 | -.3805 |
| | $\nu_1^{j=2,s}$ | -.9253 | -.1666 |
| | $\nu_1^{j=3,s}$ | -.8310 | -.2152 |
| | $\nu_1^{j=4,s}$ | -.1495 | -.4117 |
| | $\nu_1^{j=5,s}$ | -1.0675 | -.2137 |
| | $\nu_1^{j=6,s}$ | -.9370 | -.2618 |
| | $\nu_1^{j=7,s}$ | -.1402 | -.4371 |
| | $\nu_1^{j=8,s}$ | -.8293 | -.3367 |
| | $\nu_1^{j=9,s}$ | -.7275 | -.3729 |
| full loan take-up in $t-1$ | $\nu_2^{\ell=0}$ | 1.0552 | |
| | $\nu_2^{\ell=1/2}$ | 2.4043 | |
| | $\nu_2^{\ell=1}$ | 3.8192 | |
| partial loan take-up in $t-1$ | $\nu_3^{\ell=0}$ | 1.7431 | |
| | $\nu_3^{\ell=1/2}$ | 2.6507 | |
| | $\nu_3^{\ell=1}$ | 2.5835 | |
| (high school GPA $\geq P90$) | $\nu_4^{h=0}$ | -.1791 | |
| | $\nu_4^{h=1/2}$ | -.0093 | |
| | $\nu_4^{h=1}$ | .3059 | |
| high school science track | $\nu_5^{h=0}$ | .1621 | |
| | $\nu_5^{h=1/2}$ | .2522 | |
| | $\nu_5^{h=1}$ | .5571 | |
| year-round work in $t-1$ | $\nu_6^{h=0}$ | -5.3208 | |
| | $\nu_6^{h=1/2}$ | -3.5934 | |
| | $\nu_6^{h=1}$ | -1.5150 | |
| summer work in $t-1$ | $\nu_7^{h=0}$ | -1.0423 | |
| | $\nu_7^{h=1/2}$ | .2313 | |
| | $\nu_7^{h=1}$ | .8219 | |
| graduate | $\nu_8^{h=0}$ | -.8577 | 2.9278 |
| | $\nu_8^{h=1/2}$ | -1.0976 | 2.5993 |
| | $\nu_8^{h=1}$ | -.9887 | 3.1713 |
| relative risk aversion | $1-\lambda$ | .1562 | |
| | | $P(S_0)$ | |
| | $\zeta_0$ | -6.3658 | |
| (high school GPA $\geq P90$) | $\zeta_1^s$ | .7570 | 1.6427 |
| high school science track | $\zeta_2^s$ | -.3512 | 1.0841 |
| initial experience | $\zeta_3^s$ | -.7428 | -.3450 |

Coefficients from the utility function (eq. 6), and enrollment probability (eq. 16). Superscript indicate the choices: $j \in \{0, 9\}$, $s \in \{3, 4\}$, $h \in \{0, \frac{1}{2}, 1\}$, and $\ell \in \{0, \frac{1}{2}, 1\}$.

## D.2 Policy Simulations

Table 11: Policy Simulations, Interest Rate with Income Contingent Repayment

| | **IC4** | | | **IC10** | | |
|---|---|---|---|---|---|---|
| | **r=1%** | **r=3.1%** | **r=5%** | **r=1%** | **r=3.1%** | **r=5%** |
| **Enrollment:** | | | | | | |
| 2-3 year Program | 0.0007 | *0.3496* | -0.0008 | 0.0005 | *0.3491* | -0.0005 |
| 4-5 year Program | 0.0004 | *0.2958* | -0.0005 | 0.0004 | *0.2954* | -0.0001 |
| **Academic Outcome:** | | | | | | |
| Dropout | -0.0037 | *0.3926* | 0.0013 | -0.0030 | *0.4006* | 0.0032 |
| 2-3 year Degree | 0.0024 | *0.3026* | -0.0014 | 0.0023 | *0.2977* | -0.0020 |
| 4-5 year Degree | 0.0013 | *0.3048* | 0.0001 | 0.0008 | *0.3016* | -0.0011 |
| Weeks to Dropout | 1 | *201* | 0 | 1 | *201* | -1 |
| Weeks to 2-3 year D. | 0 | *226* | 0 | 1 | *224* | 0 |
| Weeks to 4-5 year D. | -1 | *293* | 0 | 0 | *293* | 0 |
| **Avg Yearly Aid:** | 153 | *38,590* | -93 | 144 | *38,235* | -146 |
| **Debt at Exit:** | 1,054 | *154,311* | -511 | 980 | *151,836* | -957 |
| Dropout | 1,165 | *131,756* | -1,106 | 822 | *130,189* | -623 |
| 2-3 year Degree | 859 | *149,777* | -110 | 850 | *147,400* | -591 |
| 4-5 year Degree | 691 | *188,587* | -43 | 1,028 | *185,714* | -1,140 |
| **Income at Exit:** | 637 | *311,432* | -276 | 213 | *310,346* | -1,162 |
| Dropout | 1,201 | *263,729* | -367 | 503 | *263,359* | -550 |
| 2-3 year Degree | -443 | *292,607* | -4 | -204 | *291,863* | -1,486 |
| 4-5 year Degree | -847 | *393,375* | -279 | -357 | *392,902* | -971 |
| **Student Choices:** | | | | | | |
| Year-round Work | -0.0034 | *0.2946* | 0.0024 | -0.0030 | *0.3016* | 0.0035 |
| Summer Work | 0.0029 | *0.5076* | -0.0019 | 0.0023 | *0.5023* | -0.0025 |
| Full Loan | 0.0020 | *0.6955* | -0.0010 | 0.0018 | *0.6908* | -0.0017 |
| Partial Loan | -0.0010 | *0.1156* | 0.0006 | -0.0006 | *0.1171* | 0.0009 |
| **Cost:** | | | | | | |
| per Student | 8,284 | *124,258* | -6,685 | 6,993 | *110,020* | -7,398 |
| Total (%) | 6.8767 | - | -5.5736 | 6.5070 | - | -6.8198 |
| p90/p10 of Income | -0.0271 | *12.1547* | -0.0304 | 0.0022 | *12.1013* | -0.014 |
| Discounted Utility (%) | 0.3375 | - | -0.2488 | 0.2691 | - | -0.2918 |
| **Means Testing:** | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| **Grant Share:** | 27.8% | 27.8% | 27.8% | 27.8% | 27.8% | 27.8% |
| **Loan Repayment:** | IC4 | IC4 | IC4 | IC10 | IC10 | IC10 |
| **Maximum Aid:** | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 |

The Table displays policy simulations of the effects on student choices and outcomes of changing the interest rate applied to the student debt. All other policy instruments are kept at the benchmark (pre-reform) 2001 level, the first three columns keep the income contingent rate at the benchmark 4% level, the last three columns put the income contingent rate at 10%. We display differences from the benchmark values, and percentage differences from the benchmark for Total Cost and Discounted Utility. All amounts are in real SEK 2000. The exchange rate ultimo December 2000 was 9.3955 SEK/USD and 8.8263 SEK/EUR. The means testing shown in the table is the percentage of the *prisbasbelopp* that determines the semestral threshold and the implicit income tax. The 25(15) years-annuity plan has the possibility of switching to an income contingent repayment of 5% of income, and then going back to a new 25(15) years-annuity calculated on the remaining debt.

Table 12: Policy Simulations, Interest Rate with Annuity Repayment

| | Annuity (25y) | | | Annuity (15y) | | |
|---|---|---|---|---|---|---|
| | **r=1%** | **r=3.1%** | **r=5%** | **r=1%** | **r=3.1%** | **r=5%** |
| **Enrollment:** | | | | | | |
| 2-3 year Program | 0.0042 | *0.3523* | -0.0043 | 0.0036 | *0.3426* | -0.0041 |
| 4-5 year Program | 0.0022 | *0.2972* | -0.0024 | 0.0024 | *0.2914* | -0.0020 |
| **Academic Outcome:** | | | | | | |
| Dropout | -0.0073 | *0.3976* | 0.0088 | -0.0066 | *0.4161* | 0.0069 |
| 2-3 year Degree | 0.0050 | *0.3004* | -0.0061 | 0.0038 | *0.2882* | -0.0040 |
| 4-5 year Degree | 0.0024 | *0.3019* | -0.0026 | 0.0028 | *0.2957* | -0.0029 |
| Weeks to Dropout | 1 | *201* | -1 | 1 | *198* | -1 |
| Weeks to 2-3 year D. | 1 | *225* | -1 | 1 | *223* | -1 |
| Weeks to 4-5 year D. | 0 | *293* | 0 | 1 | *292* | 0 |
| **Avg Yearly Aid:** | 380 | *38,382* | -375 | 383 | *37,485* | -368 |
| **Debt at Exit:** | 2,487 | *152,724* | -2,483 | 2,450 | *146,897* | -2,379 |
| Dropout | 2,235 | *131,183* | -2,136 | 2,038 | *126,226* | -2,141 |
| 2-3 year Degree | 2,291 | *148,055* | -2,100 | 2,065 | *143,155* | -1,752 |
| 4-5 year Degree | 2,281 | *186,455* | -2,451 | 2,690 | *180,394* | -2,546 |
| **Income at Exit:** | 1,148 | *310,474* | -1,576 | 177 | *308,661* | -1,008 |
| Dropout | 700 | *264,013* | -1,833 | -1,604 | *263,622* | -1,026 |
| 2-3 year Degree | 724 | *291,251* | -1,071 | 559 | *289,459* | -118 |
| 4-5 year Degree | 650 | *392,620* | -9 | -555 | *392,768* | -153 |
| **Student Choices:** | | | | | | |
| Year-round Work | -0.0079 | *0.2983* | 0.0087 | -0.0085 | *0.3187* | 0.0087 |
| Summer Work | 0.0061 | *0.5050* | -0.0067 | 0.0062 | *0.4895* | -0.0065 |
| Full Loan | 0.0054 | *0.6928* | -0.0048 | 0.0048 | *0.6814* | -0.0045 |
| Partial Loan | -0.0025 | *0.1161* | 0.0026 | -0.0022 | *0.1218* | 0.0024 |
| **Cost:** | | | | | | |
| per Student | 20,955 | *121,042* | -21,193 | 19,847 | *71,712* | -18,960 |
| Total (%) | 18.5199 | - | -18.3658 | 28.8835 | - | -27.1312 |
| p90/p10 of Income | 0.0476 | *12.0858* | 0.0289 | 0.026 | *12.1421* | 0.082 |
| Discounted Utility (%) | 0.7717 | - | -0.8370 | 0.7477 | - | -0.7484 |
| **Means Testing:** | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| **Grant Share:** | 27.8% | 27.8% | 27.8% | 27.8% | 27.8% | 27.8% |
| **Loan Repayment:** | 25year | 25year | 25year | 15year | 15year | 15year |
| **Maximum Aid:** | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 |

The Table displays policy simulations of the effects on student choices and outcomes of changing the interest rate applied to the student debt. All other policy instruments are kept at the benchmark (pre-reform) 2001 level, in the first three columns the repayment plan is the post-reform annuity, in the last three columns the repayment plan is a 15 year annuity. We display differences from the benchmark values, and percentage differences from the benchmark for Total Cost and Discounted Utility. All amounts are in real SEK 2000. The exchange rate ultimo December 2000 was 9.3955 SEK/USD and 8.8263 SEK/EUR. The means testing shown in the table is the percentage of the *prisbasbelopp* that determines the semestral threshold and the implicit income tax. The 25(15) years-annuity plan has the possibility of switching to an income contingent repayment of 5% of income, and then going back to a new 25(15) years-annuity calculated on the remaining debt.

Table 13: Policy Simulations, Grant Share with Income Contingent Repayment at 10%

| | | **Grant Share** | | | | | |
|---|---|---|---|---|---|---|---|
| | **IC10** | **15%** | **35%** | **45%** | **55%** | **75%** | **95%** |
| **Enrollment:** | | | | | | | |
| 2-3 year Program | *0.3491* | -0.0018 | 0.0012 | 0.0026 | 0.0040 | 0.0068 | 0.0102 |
| 4-5 year Program | *0.2954* | -0.0004 | 0.0005 | 0.0008 | 0.0011 | 0.0020 | 0.0028 |
| **Academic Outcome:** | | | | | | | |
| Dropout | *0.4006* | 0.0002 | -0.0009 | -0.0011 | -0.0028 | -0.0053 | -0.0083 |
| 2-3 year Degree | *0.2977* | -0.0019 | 0.0017 | 0.0033 | 0.0059 | 0.0101 | 0.0140 |
| 4-5 year Degree | *0.3016* | 0.0017 | -0.0007 | -0.0021 | -0.0030 | -0.0046 | -0.0056 |
| Weeks to Dropout | *201* | 0 | 0 | 0 | 0 | 0 | 0 |
| Weeks to 2-3 year D. | *224* | 0 | 1 | 1 | 2 | 3 | 4 |
| Weeks to 4-5 year D. | *293* | 0 | 0 | 0 | 0 | 0 | 0 |
| **Avg Yearly Aid:** | *38,235* | -1,097 | 701 | 1,707 | 2,777 | 5,133 | 7,750 |
| **Debt at Exit:** | *151,836* | 28,042 | -15,414 | -36,891 | -58,121 | -100,089 | -141,547 |
| Dropout | *130,189* | 23,979 | -13,194 | -51,453 | -49,560 | -85,544 | -121,284 |
| 2-3 year Degree | *147,400* | 26,985 | -14,833 | -35,636 | -56,295 | -97,141 | -137,406 |
| 4-5 year Degree | *185,714* | 34,369 | -18,993 | -45,373 | -71,441 | -122,716 | -173,229 |
| **Income at Exit:** | *310,346* | -390 | -67 | -525 | -142 | 382 | -72 |
| Dropout | *263,259* | 7 | 88 | -312 | 372 | 347 | 1,499 |
| 2-3 year Degree | *291,863* | -1,251 | 266 | 1,084 | 1,578 | 2,743 | 622 |
| 4-5 year Degree | *392,902* | -518 | -351 | -1,367 | -1,689 | -599 | -1,557 |
| **Student Choices:** | | | | | | | |
| Year-round Work | *0.3016* | 0.0064 | -0.0036 | -0.0088 | -0.0143 | -0.0253 | -0.0364 |
| Summer Work | *0.5023* | -0.0036 | 0.0004 | 0.0055 | 0.0089 | 0.0157 | 0.0224 |
| Full Loan | *0.6908* | 0.0075 | -0.0033 | -0.0088 | -0.0140 | -0.0247 | -0.0354 |
| Partial Loan | *0.1171* | -0.0012 | 0.0007 | 0.0020 | 0.0028 | 0.0047 | 0.0064 |
| **Cost:** | | | | | | | |
| per Student | *110,020* | -20,917 | 12,176 | 29,418 | 47,200 | 84,245 | 123,315 |
| Total (%) | - | -19.2559 | 11.3578 | 27.3982 | 44.0053 | 78.8498 | 116.0835 |
| p90/p10 of Income | *12.1013* | 0.0013 | 0.0501 | 0.07 | 0.092 | 0.0448 | 0.0364 |
| Discounted Utility (%) | - | -0.4272 | 0.2429 | 0.5644 | 0.9602 | 1.7261 | 2.5724 |
| **Means Testing:** | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| **Grant Share:** | 27.8% | 15.0% | 35.0% | 45.0% | 55.0% | 75.0% | 95.0% |
| **Loan Repayment:** | IC10 | IC10 | IC10 | IC10 | IC10 | IC10 | IC10 |
| **Maximum Aid:** | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 |

The Table displays policy simulations of the effects on student choices and outcomes of changing the grant share in study aid packages. We display differences from the benchmark values, and percentage differences from the benchmark for Total Cost and Discounted Utility. The benchmark is the pre-reform year 2001 with an income contingent repayment plan rate of 10%, the values for the benchmark are in levels. All other policy instruments are kept at the benchmark level. All amounts are in real SEK 2000. The exchange rate ultimo December 2000 was 9.3955 SEK/USD and 8.8263 SEK/EUR. The means testing shown in the table is the percentage of the *prisbasbelopp* that determines the semestral threshold and the implicit income tax.

Table 14: Policy Simulations, Grant Share with Annuity Repayment Plan

| | | Grant Share | | | | | |
|---|---|---|---|---|---|---|---|
| | **Annuity 25y** | **15%** | **35%** | **45%** | **55%** | **75%** | **95%** |
| **Enrollment:** | | | | | | | |
| 2-3 year Program | *0.3523* | -0.0011 | 0.0008 | 0.0019 | 0.0026 | 0.0049 | 0.0072 |
| 4-5 year Program | *0.2972* | -0.0002 | 0.0001 | 0.0002 | 0.0004 | 0.0007 | 0.0011 |
| **Academic Outcome:** | | | | | | | |
| Dropout | *0.3976* | 0.0013 | 0.0000 | -0.0012 | -0.0024 | -0.0041 | -0.0057 |
| 2-3 year Degree | *0.3004* | -0.0027 | 0.0008 | 0.0029 | 0.0050 | 0.0084 | 0.0114 |
| 4-5 year Degree | *0.3019* | 0.0015 | -0.0006 | -0.0016 | -0.0025 | -0.0042 | -0.0057 |
| Weeks to Dropout | *201* | 0 | 0 | 0 | 0 | 0 | 0 |
| Weeks to 2-3 year D. | *225* | -1 | 0 | 0 | 1 | 2 | 3 |
| Weeks to 4-5 year D. | *293* | 0 | 0 | 0 | 0 | 0 | 0 |
| **Avg Yearly Aid:** | *38,382* | -1,108 | 693 | 1,685 | 2,750 | 5,056 | 7,616 |
| **Debt at Exit:** | *152,724* | 28,044 | -15,554 | -37,136 | -58,475 | -100,773 | -142,426 |
| Dropout | *131,183* | 24,058 | -13,371 | -31,822 | -50,027 | -86,362 | -122,270 |
| 2-3 year Degree | *148,055* | 27,155 | -14,907 | -35,768 | -56,564 | -97,619 | -138,053 |
| 4-5 year Degree | *186,455* | 34,172 | -19,070 | -45,549 | -71,634 | -123,253 | -173,959 |
| **Income at Exit:** | *310,474* | -332 | -479 | -211 | -344 | 537 | -73 |
| Dropout | *264,013* | -483 | -953 | -721 | -254 | -471 | 837 |
| 2-3 year Degree | *291,251* | -710 | 740 | 1,514 | 1,276 | 3,511 | 1,641 |
| 4-5 year Degree | *392,620* | -142 | -852 | -794 | -1,379 | -103 | -1,541 |
| **Student Choices:** | | | | | | | |
| Year-round Work | *0.2983* | 0.0065 | -0.0037 | -0.0086 | -0.0137 | -0.0238 | -0.0335 |
| Summer Work | *0.5050* | -0.0037 | 0.0023 | 0.0052 | 0.0083 | 0.0144 | 0.0199 |
| Full Loan | *0.6928* | 0.0073 | -0.0035 | -0.0088 | -0.0140 | -0.0254 | -0.0371 |
| Partial Loan | *0.1161* | -0.0016 | 0.0008 | 0.0017 | 0.0029 | 0.0049 | 0.0072 |
| **Cost:** | | | | | | | |
| per Student | *121,042* | -20,339 | 11,629 | 27,968 | 44,623 | 78,587 | 113,511 |
| Total (%) | - | -16.9243 | 9.7446 | 23.4739 | 37.4546 | 66.2208 | 96.0126 |
| p90/p10 of Income | *12.0858* | 0.0276 | 0.0288 | 0.0806 | 0.0898 | 0.0698 | 0.0549 |
| Discounted Utility (%) | - | -0.4627 | 0.2327 | 0.5178 | 0.9123 | 1.5590 | 2.2587 |
| **Means Testing:** | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| **Grant Share:** | 27.8% | 15.0% | 35.0% | 45.0% | 55.0% | 75.0% | 95.0% |
| **Loan Repayment:** | 25year | 25year | 25year | 25year | 25year | 25year | 25year |
| **Maximum Aid:** | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 | 64,232 |

The Table displays policy simulations of the effects on student choices and outcomes of changing the grant share in study aid packages. We display differences from the benchmark values, and percentage differences from the benchmark for Total Cost and Discounted Utility. The benchmark is the pre-reform year 2001 with the repayment plan for the debt changed to the post-reform annuity, the values for the benchmark are in levels. All other policy instruments are kept at the benchmark level. All amounts are in real SEK 2000. The exchange rate ultimo December 2000 was 9.3955 SEK/USD and 8.8263 SEK/EUR. The means testing shown in the table is the percentage of the *prisbasbelopp* that determines the semestral threshold and the implicit income tax.