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Accounting for the Changing Role of Family Income
in Determining College Entry

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Abstract

Assessing the importance of borrowing constraints for college entry is key for education policy analysis in the U.S. economy. I present a computable dynamic general equilibrium model with overlapping generations and incomplete markets that allows me to measure the fraction of households constrained in their college entry decision. College education is financed by family transfers and public subsidies, where transfers are generated through altruism on part of the parents. Parents face a trade-off between making transfers to their children and own savings. Ceteris paribus, parents who expect lower future earnings transfer less and save more. Data from the 1986 Survey of Consumer Finances give support to this mechanism. I show that this trade-off leads to substantially higher estimates of the fraction of constrained households compared to the results in the empirical literature (18 instead of 8 percent). The model also predicts that an increment in parents' earnings uncertainty decreases their willingness to provide transfers. In combination with rising returns to education, which makes college going more attractive, this boosts the number of constrained youths and explains why family income has become more important for college access over the last decades in the U.S. economy.

Keywords: College Enrolment, Borrowing Constraints,Parental Transfers, Household Savings, Dynamic General Equilibrium Models

JEL classification: I20, I22, D58, D91

1 Introduction

In the United States, the wage premium of college graduates relative to high school graduates increased by around 30 percent between 1980 and 2000 (Katz and Autor (1999)). This period was also characterized by a dramatic rise of college tuition fees and an amplification of the within-group earnings inequality. College participation rates stagnated, while the enrolment gaps between students from different family income groups widened (Ellwood and Kane (2000), Carneiro and Heckman (2003) and Kane (2006)).

This suggests that financial constraints prevent a larger share of low-income households from sending their children to college, leading to a sluggish adjustment of college participation despite the surge in the college premium Kane (2006). Whether this is true or not is subject to an ongoing debate in the empirical literature. Carneiro and Heckman (2002) and Carneiro and Heckman (2003) argue that short-term cash constraints around college age are binding only for a small fraction of households. They find that long-term factors (family background variables) which affect pre-college education can account for the main part of enrolment gaps by income. However, it is not clear to what extend long-term factors can account for the widening of the enrolment gaps observed over time. Belley and Lochner (2007) document that the impact of family income on college attendance rates increased dramatically between 1980 and 2000, even after controlling for family background. They also document that the enrolment patterns observable in the data are at variance with a simple model of college attendance, even if they allow for borrowing constraints. Hence, there remains considerable disagreement about the role of borrowing constraints (Kane (2006)).

In this paper, I want to shed further light on the role of financial constraints. In particular, I address the following two questions:

1. Are borrowing constraints quantitatively important in determining college entry?

2. As the economic environment has changed in the U.S. over the course of the last decades, have borrowing constraints become more limiting?

I answer these questions with the help of a computable overlapping generation model that endogenizes the college enrolment decisions. Borrowing by young households for college education is not permitted; they thus have to relay on parental transfers and public support in the form of subsidies in order to cover college expenses. This allows me to measure the fraction of adolescents that would like to attend college but cannot do so because of market imperfections. I derive the distribution of parental transfers endogenously in my model; this enables me to study the impact of the recent changes in the economic environment on college attendance and on borrowing constraints.

I show that the enrolment gaps produced by the model narrow considerably once I control for so-called long-term factors. Thus, the findings are consistent with Carneiro and Heckman (2002). Yet, I find that a substantial fraction (18 percent) of all households are borrowing constrained. This shows that even when enrolment gaps are narrow, borrowing constraints may affect a large part of the population. The results thus help to resolve the disagreement in the empirical literature with respect to the quantitative importance of borrowing constraints.

I then examine how the economy behaves if I increase the college premium, the tuition fees and the earnings inequality to values observable in the U.S. economy around 2000. I find that that the model replicates the college enrolment patterns presented in Belley and Lochner (2007) very well. In particular, the model predicts (i) a slight increase in the number of college graduates, (ii) a substantial increment in the impact of family income on the college enrolment of young households, and a (iii) stable ability-enrolment pattern. The model predicts that the fraction of constrained households rose sharply from 18 percent to 40 percent between 1980 and 2000. The results thus show that all enrolment patterns can be explained within the same framework, and that these patterns are consistent with an increase in the number of constrained households.

Despite the sharp rise in the number of households affected, the model implies that the correlation of educational attainment across generations actually decreased. This is perhaps surprising, as the literature in general assumes that tighter borrowing constraints lead to a higher persistence of education across generations. Ellwood and Kane (2000) as well as Belley and Lochner (2007) document that the correlation between parental education and college enrolment of the child has become weaker over the course of the last decades.

Understanding the behavior and the determinants of parental transfers is crucial for my results. The model endogenously accounts for the initial distribution of wealth of young households by assuming that altruistic parents provide transfers to their children.[1] More precisely, I assume that old households ('parents') are altruistic and incorporate the utility of their descendants ('young households') in their maximization problem. I follow Laitner (2001) and allow for imperfect altruism; parents may weight their children's utility less than their own utility. In the model, I distinguish between two different levels of human capital ('college education' and 'high school') and endogenize college choice. Parental transfers can be used to finance college education, which is assumed to be costly.

I also allow for idiosyncratic labor income shocks, which enables me to analyze the effects of the rise of the within-group inequality that has been documented for the U.S. (Krueger and Perri (2006)). Incorporating inequality within generations and education levels also allows me to distinguish different ability levels.

I solve the model numerically and calibrate the parameters such that key features of the U.S. economy are matched. I then compare two different steady-state equilibria in order to evaluate changes over time.

Altruism implies that there exists a trade-off for parents between investing in their own future or in the future of their children. This means that even children from rich families

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[1]Gallipoli et al. (2006), and Ionescu (2007), among others, assume that the initial distribution of wealth is exogenous for young households. Hanushek et al. (2004) assume that transfers are generated by assuming a 'joy-of-giving' motive, which implies that transfers depend only on parental wealth but not on the economic situation of the child. This is at odds with empirical evidence showing that inter-vivos transfers are negatively correlated with the child's permanent income (Cox (1990)). Restuccia and Urrutia (2004) and Cunha (2005) use an altruistic framework to analyze the parental trade-off between human capital investments at different stages of life. Because their focus is on early education, they model parents only up the age when their children enter college. I show that all stages of the parental life cycle are important in order to understand transfer behavior.

can be constrained in their college decision because their parents are not willing to provide enough resources. Indeed, I show that the transfer flows generated by the model imply that parents consider their offspring's utility by 30 percent less than their own utility. This worsens the position of the child and pushes the number of constrained households up. In fact, I show that the parental trade-off explains why borrowing constraints are binding for a substantial fraction of the population, even though enrolment gaps across different income groups appear to be narrow, after controlling for long-term factors.

The model also allows me to study how the trade-off between savings and transfers evolves over time. I show that the interplay between the rise in the between-group and in the within-group inequality explains why borrowing constraints became more limiting over time. The rise in the college premium (between-group inequality) makes college investment more profitable, even for low-ability youths. However, their parents accumulate additional savings in order to self-insure against the increase in the within-group inequality, which I model as an increment in the variance of earnings shocks. This implies that accumulating more savings is preferred over investing in college education for parents with low-ability children. It follows from the model that the increase in the enrolment gap is more pronounced for low-ability students. This is exactly what one observes in the data as well (Belley and Lochner (2007)).

Since earnings of high school graduates fluctuate more than the earnings of college graduates (Hubbard et al. (1995)) and earnings account for a bigger fraction of total income for high school graduates, this channel also helps to explain the degree of intergenerational persistence of educational attainment. In my framework, children of college graduated parents are – all other things equal – up to 5 percent more likely to enter college, because their parents need to provide less savings for their own future. Using transfers and savings data from the 1986 Survey of Consumer Finances (SCF), I find empirical support for this key prediction of the model: high school graduates save significantly more than college graduates during the last 20 years before retirement if one controls for wealth and income. In turn, college graduates in that age group provide significantly more transfers.

The remainder of the paper is structured as follows. I present the model in section 2. Section 3 introduces the equilibrium definition, while the calibration is explained in Section 4. We discuss our results in Section 5. Finally, Section 6 concludes.

2 Model

I consider a life cycle economy with altruistic parents. As in Laitner (2001), altruism may be imperfect. Parents provide transfers to their children. They face constraints on their resources: all credit markets are closed, implying that they can neither borrow against their own future income nor against the future income of their descendants. I allow for idiosyncratic productivity shocks during working life. Moreover, I endogenize college choice by assuming that parental transfers can be used to pay for college education. These assumptions allow me to study the effects of an endogenously generated initial distribution of assets on college enrolment, and to analyze the determinants of the initial asset distribution in a realistic life cycle setting.

2.1 The Life Cycle of a Household

There is a continuum of agents with total measure one. I assume that the size of the population is constant over time. Let j denote the age of an agent, $j \in J = \{1, 2, ..., J^{\max}\}$. Agents enter the economy when they turn 23 (model period $j = 1$). Before this age, they belong to their parent household and depend on its economic decisions. During the first 40 years of their 'economic' life, agents work. This implies that the agents work up to age 62 (model period $J^{work} = 40$). Retirement takes place at the age of 63 ($j = 41$), which is mandatory. When agents turn 53 ($j = 31$), their children of age 23 form their own household. This implies a generational age gap of 30 years. It is assumed that there is one child household for each parent household. Agents face a declining survival probability after their children leave home. Terminal age is 83 ($J^{\max} = 60$). Since annuity markets are closed by assumption, agents may leave some wealth upon the event of death. The remaining wealth of a deceased parent household is passed on to its child household.

2.2 Transfers

At age 53, a parent's household child becomes independent and forms its own household. Gale and Scholz (1994) report that the mean age of givers is 55 years in the 1983-1986 Survey of Consumer Finances. I assume that transfers are generated by one-sided altruism, that is, parents care about the lifetime well-being of their mature children, but not the other way round. I abstract from strategic interaction and assume that parents provide part of their own wealth as an initial endowment at the beginning of the economic life of the child household. Part of this endowment (or all of it) can be in form of investment in human capital. It is important to notice that the assumption of altruism implies that parents will combine education investment and financial transfers in such a way that the child's lifetime utility is maximized given the total amount of wealth that parents wish to pass on to their descendants. Put differently, children may not agree with their parents on the total amount which is being transferred, but certainly on the mix between human capital investment and financial transfers.[2]

The assumptions regarding the life cycle and the transfer behavior are summarized in Figure 1.

2.3 Labor Income Process

During each of the 40 periods of their working life, agents supply one unit of labor inelastically. The productivity of this labor unit of an j-year old agent is measured by $\varepsilon_j^e \eta^{j,e}$, where $\left\{\varepsilon_j^e\right\}_{j=1}^{J^w}$ is a deterministic age profile of average labor productivity of an agent with education level e:

$$e \in E = \{\text{highschool}(hs), \text{college}(col)\} \tag{1}$$

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[2]In the following, I will use the terms 'financial transfers', 'inter vivos transfers' and 'inter vivos transfers' as labels for capital transfers which take place during lifetime of both donor and recipient.
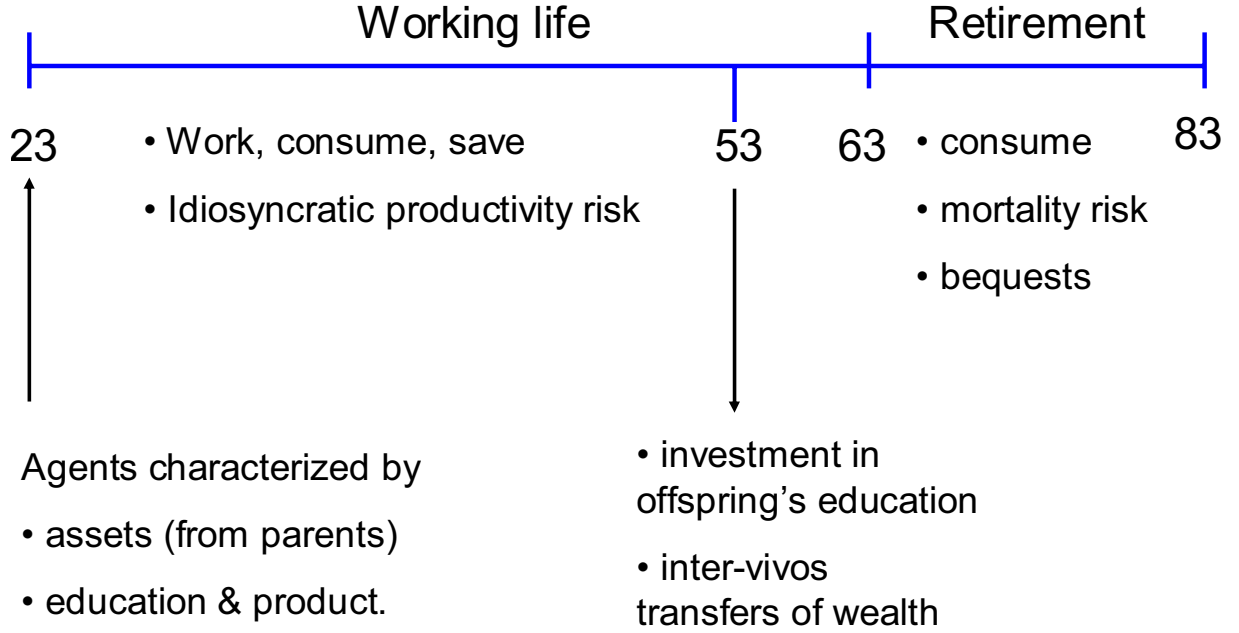
Figure 1: Life cycle and Generation Structure

For retired agents, $\varepsilon_j^e = 0$.

$\eta^{j,e}$ describes the stochastic labor productivity status of a j-year old agent with education level e. Given the level of education e, I assume that the labor productivity process is identical and independent across agents (no aggregate productivity shocks) and that it follows a finite-state Markov process with stationary transition probabilities over time. More specifically,

$$Q(\eta^{hs}, N^{hs}) = \Pr(\eta^{j+1,hs} \in N^{hs} | \eta^{j,hs} = \eta^{hs}) \tag{2}$$

for high-school graduates. $N^{hs} = \left\{\eta_1^{hs}, \eta_2^{hs}, ..., \eta_n^{hs}\right\}$ is the set of possible realizations of the productivity shock η^{hs}. Similarly, I express the stochastic labor productivity process for college graudates as

$$Q(\eta^{col}, N^{col}) = \Pr(\eta^{j+1,col} \in N^{col} | \eta^{j,col} = \eta^{col}) \tag{3}$$

with $N^{col} = \left\{\eta_1^{col}, \eta_2^{col}, ..., \eta_n^{col}\right\}$.

I assume that children of college graduates have - on average - productivity levels above average, while high school graduates draw shocks that are below average. Carneiro et al. (2006) show that maternal education has a strong positive impact on children's cognitive achievement. I interpret the initial draw as a proxy for ability during adolescence, that is, ability before college education or labor market entry occurs. In particular, I assume that the probability to dropout from college decreases with the level of the initial productivity shock. Consistent with empirical evidence regarding the intergenerational correlation of schooling, this and the the fact that the productivity in the first period of working life depends on parental education, implies that college education is positively correlated across

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generations. The parental education level influences only the initial draw of the productivity shock: From the second period onwards, the shocks evolve according to their respective stochastic process. More specifically, I assume that the initial shock is governed by the following transition matrices:

$$Q^{initial,hs}(i, i \in I = \{1, 2, ..., n\}) = \Pr(i, i \in \{1, 2, ..., n\} \,|\, \eta^{30,hs} = \eta^{hs}) \tag{4}$$

$$Q^{initial,col}(i, i \in I = \{1, 2, ..., n\}) = \Pr(i, i \in \{1, 2, ..., n\} \,|\, \eta^{30,col} = \eta^{col}) \tag{5}$$

2.4 Investment in Education and Borrowing Constraints

I distinguish between two levels of education, high school and college.[3] Upon entering the economy, all households possess a high school degree. They (or their parents) decide on investing in college education, before any other economic action is taken. Investment in college education takes place at the beginning of the lifetime. College education requires large investments that are risky and lumpy. It is risky because there is a certain probability that the child drops out. In addition, the earnings stream is stochastic which increases the uncertainty. Dropout rates are high in the U.S., as well as in other OECD countries (see Akyol and Athreya (2005)). Consistent with evidence from the empirical literature, see e.g. Stinebrickner and Stinebrickner (2007), I assume that children with lower levels of ability are more likely to drop out. Since dropout rates are higher during the first years of the college studies (when returns to college education are low), dropouts face the same earnings process as high school graduates. Consequently, only students who actually graduate from college enjoy higher mean earnings during their working life. This implies that college education is an indivisible and lumpy investment.[4] Transfers and savings cannot be negative; parents are thus required to finance their children's college education out of their own resources.

2.5 Taxes and Social Security Benefits

During working life, households pay a proportional tax on their labor income. All households also pay a proportional tax on their capital income.

Tax revenue from labor income and capital income taxation is used by an infinitely lived government in order to finance pension benefits *pen*. I assume that pensions are independent of the employment history of a retiree.

3 The Households' Recursive Problem

I distinguish between young households (children) and parent households. I use a subscript y for young households and a subscript p for parental households.

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[3]The share of high school dropouts is small in the data, see Rodriguez et al. (2002) who measure a share of 17 percent in the 1998 SCF.

[4]See Akyol and Athreya (2005) and the references cited therein.

3.1 Young households

When parents die, young households inherit the wealth of their parents. I assume that young households observe their parental wealth holdings. Therefore, I need to distinguish between child households with deceased parents and young households that are expecting to inherit. I make the following timing assumption: death takes place at the end of the period, after the consumption and savings decision has been made. Bequests are then distributed at the beginning of the next period.

3.1.1 Young households with deceased parents

Consider a household during working age ($j \in J^w = \{1, ..., 30\}$) whose parent household is dead. At age j, this household consumes $c_{y,d}$ and has end-of-period wealth holdings of $a'_{y,d}$, where the subscript y, d indicates a young household with deceased parents. Given a discount factor β, a rate of return to capital r, a wage rate per efficiency unit of labor w, tax rates on labor income and capital income τ_w and τ_k, the optimization problem of this household reads as

$$V_{y,d}(s_{y,d}) = \max_{c_{y,d}, a'_{y,d}} \left\{ u(c_{y,d}) + \beta \sum_{\eta' \in N^e} V_{y,d}(s'_{y,d}) Q(\eta, \eta') \right\} \forall j \in \{1, ...30 - 1\} \quad (6)$$

where $V_{y,d}(.)$ is the value function of a young household with deceased parents and $s_{y,d}$ is the vector of state variables in period j, which is given by

$$s_{y,d} = (a_{y,d}, e, \eta^{j,e}, j) \quad (7)$$

Agents maximize (6) subject to the budget constraint[5]

$$a'_{y,d} = (1 + r(1 - \tau_k))a_{y,d} + (1 - \tau_w)\varepsilon_j^e \eta^{j,e} w - c_{y,d} \quad (8)$$

$$a'_{y,d} \geq 0$$

The state space $\mathbf{S}_{y,d}$ of an household of type y, d thus includes four variables: own asset holdings, $a_{y,d} \in \mathbb{R}_+$, education level, $e \in E$, stochastic productivity, $\eta^{j,e} \in N^{j,e}$, and age $j \in \{1, ..., 30\}$. Notice that $\mathbf{S}_{y,d} = \mathbb{R}_+ \times E \times N^e \times \{1, ..., 30\}$. Let $\mathbf{P}(E)$, $\mathbf{P}(N^e)$ and $\mathbf{P}\{1, ..., 30\}$ be the power sets of E, N^e and $\{1, ..., 30\}$, respectively, and let $\mathbf{B}(\mathbb{R}_+)$ the Borel σ-algebra of $\mathbb{R}_+$. It follows that $\mathcal{S}_{y,d} = \mathbf{B}(\mathbb{R}_+) \times \mathbf{P}(E) \times \mathbf{P}(N^e) \times \mathbf{P}(J^w)$ is a σ-algebra on $\mathbf{S}_{y,d}$ and that $\mathcal{M}_{y,d} = (\mathbf{S}_{y,d}, \mathcal{S}_{y,d})$ is a measurable space. I will assume that the value function $V_{y,d} : \mathbf{S}_{y,d} \to \mathbb{R}$ and the policy functions $c_{y,d} : \mathbf{S}_{y,d} \to \mathbb{R}_+$ and $a'_{y,d} : \mathbf{S}_{y,d} \to \mathbb{R}_+$ are measurable with respect to $\mathcal{M}_{y,d}$.

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[5]Notice that for $j = 30$, the value function reads as

$$V_{y,d}(s_{y,d}) = \max_{c_{y,d}, a'_{y,d}} \left\{ u(c_{y,d}) + \beta \sum_{\eta' \in N^e} V_{p,1}(s_{p,1}) Q(\eta, \eta') Q^{initial,e}(\eta, di) \right\}$$

When $j = 30$, child households become parent household in $j + 1$. This implies that they observe their offspring 's initial productivity level which becomes part of their state vector $s_{p,1}$.

3.1.2 Young households whose parents are alive

At any age $j \in \{1, ..., 30\}$, a household whose parents are still alive consume $c_{y,a}$ and have end-of-period wealth holdings of $a'_{y,a}$, where y, a denotes a young household whose parents are alive. Its parent household has wealth holdings of $a^p_{y,a}$. Since the child does not know when the parent household dies, the value function is a weighted sum of the utility it receives if the parent household dies and the utility which is obtained if the parent continues to live for another period, where the parental survival probability ψ_{j+30} serves as a weight. The optimization problem can thus be described by the following functional equation:

$$V_{y,a}(s_{y,a}) = \max_{c_{y,a}, a'_{y,a}} \left\{ \begin{array}{c} u(c_{y,a}) + \beta(1 - \psi_{j+30}) \sum_{\eta' \in N^e} V_{y,d}(s'_{y,d}) Q(\eta, d\eta') \\ + \beta \psi_{j+30} \sum_{\eta' \in N^e} V_{y,a}(s'_{y,a}) Q(\eta, d\eta') \end{array} \right\} \tag{9}$$

$$\forall j \in \{1, ...30 - 1\}\,^6$$

where ψ_{j+30} is the survival probability of the parent household, $V_{y,a}(s_{y,a})$ denotes the value function given the state vector $s_{y,a}$, where $s_{y,a}$ is described by

$$s_{y,a} = (a_{y,a}, a^{p'}_{y,a}, e, \eta^{j,e}, j) \tag{10}$$

Notice that children observe only their parents end-of-period asset holdings. This implies that the law of motion of parental asset holdings is not part of the information set of the child household.[7]

The household maximizes (9) subject to its current period budget constraint

$$a'_{y,a} = (1 + r(1 - \tau_k))a_{y,a} + (1 - \tau_w)\varepsilon^e_j \eta^{j,e} w - c_{y,a} \tag{11}$$

$$a'_{y,a} \geq 0$$

If the parent household dies in period $j - 1$, the flow budget constraint becomes

$$a'_{y,d} = (1 + r(1 - \tau_k))(a_{y,a} + a^p_{y,a}) + (1 - \tau_w)\varepsilon^e_j \eta^{j,e} w - c_{y,a} \tag{12}$$

$$a'_{y,d} \geq 0$$

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[6]If $j = 30$, the child household knows that its parent household will die for sure in the current period. The Bellman equation thus reads as

$$V_{y,a}(s_{y,a}) = \max_{c_{y,a}, a'_{y,a}} \left\{ u(c_{y,d}) + \beta \sum_{\eta' \in N^e} V_{p,1}(s_{p,1}) Q(\eta, \eta') Q^{initial,e}(\eta, di) \right\}$$

[7]I also experimented with a model in which children use the policy function of their respective parents' problem in order to update their information about expected bequests. This adds another to variables to the child household's state space, namely the education and the productivity level of the parent households, thereby resulting in a dramatic increase in CPU time needed to solve the model. I found that parental asset holdings alone are sufficient to forecast future bequests. Including education and productivity did not change the child's behavior at all.

Because a child household keeps track of its parents wealth holding, I need to extend the state space $\mathbf{S}_{y,a}$ by $a_{y,a}^p \in \mathbb{R}_+$. The state space contains now two continuous variables, and is given by $\mathbf{S}_{y,a} = \mathbb{R}_+ \times \mathbb{R}_+ \times E \times N^e \times \{1, ..., 30\}$. Similar to the problem of a child household with deceased parents given above, I define a measurable space $\mathcal{M}_{y,a} = (\mathbf{S}_{y,a}, \mathcal{S}_{y,a})$, with respect to which $V_{y,a} : \mathbf{S}_{y,a} \rightarrow \mathbb{R}$, $c_{y,a} : \mathbf{S}_{y,a} \rightarrow \mathbb{R}_+$ and $a'_{y,a} : \mathbf{S}_{y,a} \rightarrow \mathbb{R}_+$ are measurable.

3.2 Parent Households

Consider now a parent household, $31 \leq j \leq J^{\max}$. A parent household works during the first 10 years and is retired afterwards. The household faces a declining survival probability, $\psi_j < 1$. In the following, I define the parent household's problem in three different stages.

3.2.1 Parent Household, Working

$$V_{p,w}(s_{p,w}) = \max_{c_{p,w}, a'_{p,w}} \left\{ u(c_{p,w}) + \beta \psi_j \sum_{\eta' \in N^e} V_{p,w}(s'_{p,w}) Q(\eta, \eta') \right\} \forall j \in \{32, ...40\} \qquad (13)$$

where $V_{p,w}(.)$ is the value function of a young household with deceased parents and $s_{p,w}$ is the vector of state variables in period j given by

$$s_{p,w} = (a_{p,w}, e, \eta^{j,e}, j) \qquad (14)$$

Agents maximize (13) subject to the budget constraint

$$a'_{p,w} = (1 + r(1 - \tau_k))a_{p,w} + (1 - \tau_w)\varepsilon_j^e \eta^{j,e} w - c_{p,w} \qquad (15)$$

$$a'_{p,w} \geq 0$$

The state space is given by $\mathbf{S}_{y,a} = \mathbb{R}_+ \times E \times N^e \times \{32, ...40\}$. I define a measurable space $\mathcal{M}_{p,w} = (\mathbf{S}_{p,w}, \mathcal{S}_{p,w})$, with respect to which $V_{p,w} : \mathbf{S}_{p,w} \rightarrow \mathbb{R}$, $c_{p,w} : \mathbf{S}_{p,w} \rightarrow \mathbb{R}_+$ and $a'_{p,w} : \mathbf{S}_{p,w} \rightarrow \mathbb{R}_+$ are measurable.

3.2.2 Parent Household, Retired

This household receives social security benefits, pen, and chooses consumption $c_{p,r}$ and its end-of-period wealth level $a'_{p,r}$. The optimization problem of this household can be written in recursive formulation as follows:

$$V_{p,r}(s_{p,r}) = \max_{c_{p,r}, a'_{p,r}} \left\{ u(c_{p,r}) + \beta \psi_j V_{p,r}(s'_{p,r}) \right\} \qquad (16)$$

$$\forall j \in \{41, ... J^{\max} - 1\}$$

where $V_{p,r}(s_{p,r})$ is the value function, given the state vector $s_{p,r}$. It follows that

$$s_{p,r} = (a_{p,r}, j) \qquad (17)$$

The household maximizes (16) subject to

$$a'_{p,r} = (1 + r(1 - \tau_k))a_{p,r} + pen - c_{p,r} \tag{18}$$

$$a'_{p,r} \geq 0$$

In the terminal period $J^{\max}$, (16) reduces to

$$V_{p,r}(s_{p,r}) = \max_{c_{p,r}} \{u(c_{p,r})\} \tag{19}$$

subject to

$$c_{p,r} \leq (1 + r(1 - \tau_k))a_{p,r} + pen \tag{20}$$

The state space is now given by $\mathbf{S}_{p,r} = \mathbb{R}_+ \times \{41, ..., J^{\max}\}$. I construct a measurable space $\mathcal{M}_{p,r} = (\mathbf{S}_{p,r}, \mathcal{S}_{p,r})$, with respect to which I define $V_{p,r} : \mathbf{S}_{p,r} \to \mathbb{R}$, $c_{p,r} : \mathbf{S}_{p,r} \to \mathbb{R}_+$ and $a'_{p,r} : \mathbf{S}_{p,r} \to \mathbb{R}_+$ to be measurable.

3.2.3 Parent Household, First Period

In their first period ($j = 31$), parents incorporate the discounted lifetime utility of their children. They choose their own savings $a'_{p,1}$ and the transfers to their child household in such a way that their total utility is maximized. Transfers can be in form of assets (tra) and investment in education (ed). Recall that the education level is a binary variable, that is, $ed \in \{0, 1\}$, where $ed = 0$ if parents choose not to send their children to college and $ed = 1$ if parents send their children to college. Expressed in terms of a Bellman equation, the decision problem of a parent household at $j = 31$ reads as

$$V_{p,1}(s_{p,1}) = \max_{c_{p,1},a'_{p,1},tra,ed} \left\{ \begin{array}{c} u(c_p) + \beta\psi_{31}V_p(s'_p) \\ +\varsigma \left(E\left[V_{y,a}(s_{y,a})|ed = 1\right] + E\left[V_{y,a}(s_{y,a})|ed = 0\right]\right) \end{array} \right\} \tag{21}$$

where ς is the intergenerational discount factor. I allow for imperfect altruism, that is, $0 \leq \varsigma \leq 1$. If $\varsigma = 0$, parents care only about their own utility. The model thus nests a pure life cycle economy ($\varsigma = 0$) and a dynastic model ($\varsigma = 1$) as extreme cases. Both Laitner (2001) and Nishiyama (2002) show that the observable flow of transfers is consistent with an intermediate case. Clearly, the degree of altruism matters for parental transfer behavior. Notice that it influences only the total amount of resources which is transferred, but does not have any effect on the division into education investment and financial transfers.

$V_{p,1}(s_{p,1})$ is the value function for a given state vector $s_{p,1}$, where

$$s_{p,1} = (a_{p,1}, e, \eta^{j,e}, i) \tag{22}$$

Notice that the initial productivity level i becomes part of the parent household's state space because the child may drop out before graduating. i determines the probability to drop out. Together with the fact that the income stream is stochastic, this implies that investment in college risky. Therefore, whether parents invest in the children's education beyond high school depends on the difference between $E\left[V_{y,a}(s_{y,a})|ed = 1\right]$, the expected utility from

investing, and $E\left[V_{y,a}(s_{y,a})|ed=0\right]$, the value if they do not invest. More precisely, the expected utility from investing is given by

$$E\left[V_{y,a}(s_{y,a})|ed=1\right] = \left\{ \begin{array}{c} \lambda(i)V_{y,a}(tra, a_{p,1}, col, \eta^{1,col}, 1) \\ +(1-\lambda(i))V_{y,a}(tra, a_{p,1}, hs, \eta^{1,hs}, 1) \end{array} \right\} \quad (23)$$

where $\lambda(i)$ is the probability that the child household completes college education successfully. The expected utility is thus a weighted average of the expected lifetime utility if the child completes education and of the expected value of the household if it does not complete education. If the child household enters college but does not complete college education, the child household faces the same value function as a child household which does not enter college education. The parental budget constraint is given by

$$a'_{p,1} = (1 + r(1-\tau_k))a_{p,1} + (1-\tau_w)\varepsilon_j^e \eta^{j,e} w + \nu_{|ed=1}(a_{p,1}, \varepsilon_j^e \eta^{j,e} w) - tra - \kappa_{|ed=1} - c_{p,1} \quad (24)$$

$$a'_{p,1} \geq 0$$

where ν denotes the college subsidy the household receives if $ed = 1$, κ denotes the fixed college expenses that the parent household pays. The subsidy level ν is a function of family resources available for college investment. In the U.S., most programs are targeted towards students of low income families. In this case, the amount of subsidies depends negatively on the amount of family resources (see e.g. Feldstein (1995)).

Note that children may also receive end-of-life bequests. Because average bequests are higher the more the parent saves in period $j = 31$, the value function of the child, $V_{y,a}(s_{y,a})$, is increasing and concave in $a_{p,1}$. Because the parent household incorporates $V_{y,a}(s_{y,a})$ in its decision problem in $j = 31$, it also incorporates the utility from leaving bequests. This establishes a trade-off between transferring resources in the form of inter vivos transfers or in the form of end-of-life bequests. Note that this mechanism would also work in the presence of a perfect annuity market.

Using the fact that the state space of parents in their first period is given by $\mathbf{S}_{p,1} = \mathbb{R}_+ \times E \times N^e \times \{1, 2, ..., i\}$, I construct a σ-algebra on $\mathbf{S}_{p,1}$ as $\mathcal{S}_{p,1} = \mathbf{B}(\mathbb{R}_+) \times \mathbf{P}(\{1, 2, ..., i\}) \times \mathbf{P}(E) \times \mathbf{P}(N^e)$ where $\mathbf{P}(\{1, 2, ..., i\})$ is the power set of $\{1, 2, ..., i\}$. $\mathcal{M}_{p,1} = (\mathbf{S}_{p,1}, \mathcal{S}_{p,1})$ is then a measurable space, which implies that $V_{p,1} : \mathbf{S}_{p,1} \to \mathbb{R}$, $c_{p,1} : \mathbf{S}_{p,1} \to \mathbb{R}_+$, $a'_{p,1} : \mathbf{S}_p \to \mathbb{R}_+$, $tra : \mathbf{S}_{p,1} \to \mathbb{R}_+$ and $ed : \mathbf{S}_{p,1} \to \{0, 1\}$ are measurable on $\mathcal{M}_{p,1}$.

3.3 The Firm's Problem

There is a continuum of firms, which I normalize to have total measure one. Firms are competitive and take all prices as given. Thus, I assume a single representative firm. This representative firm uses aggregate physical capital K and aggregate labor measured in efficiency units L to produce a single identical output good Y. The profit-maximizing conditions of the representative firm are

$$r + \delta = F_K(K, L) \quad (25)$$

$$w = F_L(K, L) \quad (26)$$

where $F(K, L)$ is a constant returns to scale production function.

3.4 The Government's Problem

The infinitely lived government administers the pension system and distributes college subsidies. The government finances pension benefits and subsidies by issuing a payroll tax on labor and capital income. I impose that the budget of the government has to be balanced in each period. Let Φ be a probability measure defined over the measurable spaces $\mathcal{M}_{y,d}$, $\mathcal{M}_{y,a}$, $\mathcal{M}_{p,1}$, $\mathcal{M}_{p,w}$ and $\mathcal{M}_{p,r}$, which result from the household problem as stated above.[8] The government computes old-age pension benefits, pen, as the average lifetime income of a high-school graduate times a social security replacement ratio:

$$pen = rep\frac{w\left(\int_{\mathbb{R}_+\times\{hs\}\times N^{hs}\times J^w}\varepsilon_j^{hs}\eta^{j,hs}d\Phi + \int_{\mathbb{R}_+\times\{hs\}\times N^{hs}\times J^w}\varepsilon_j^{hs}\eta^{j,hs}d\Phi\right)}{\int_{\mathbb{R}_+\times\{hs\}\times N^{hs}\times J^w}d\Phi + \int_{\mathbb{R}_+\times\{hs\}\times N^{hs}\times J^w}d\Phi} \tag{27}$$

I assume that tax rate levied on capital, τ_k, is determined exogenously. The government's problem thus reduces to adjusting tax rate on labor income τ_w such that budget is balanced:

$$\tau_w = \frac{pen\left(\int_{\mathbf{s}_{p,r}}d\Phi\right) + \Xi - \tau_k rK}{wL} \tag{28}$$

where the total amount of college subsidies Ξ is given by

$$\Xi = \int_{\mathbf{s}_{p,1}}\nu_{|ed=1}d\Phi \tag{29}$$

4 Definition of a Stationary Competitive Equilibrium

I now define the equilibrium that I study:

Definition 1 *Given a replacement rate, rep, and a tax rate for capital income, τ_k, a college subsidy rule ν, a Stationary Recursive Competitive Equilibrium is a set of functions $V_{y,d}(s_{y,d})$, $V_{y,a}(s_{y,a})$, $V_{p,1}(s_{p,1})$, $V_{p,w}(s_{p,w})$, $V_p(s_p)$, $c_{y,d}(s_{y,d})$, $c_{y,a}(s_{y,a})$, $c_{p,1}(s_{p,1})$, $c_{p,w}(s_{p,w})$, $c_p(s_p)$, $a'_{y,d}(s_{y,d})$, $a'_{y,a}(s_{y,a})$, $a'_{p,1}(s_{p,1})$, $a'_{p,w}(s_{p,w})$, $a'_p(s_p)$, $tra(s_{p,1})$, $ed(s_{p,1})$, non-negative prices of physical capital and of effective labor, $\{r,w\}$, and set of probability measures on the state spaces of the respective household problem as defined in sections (3.1.2)-(3.2.3) such that the following hold:*

1. *Given prices and policies, $V_{y,d}(s_{y,d})$, $V_{y,a}(s_{y,a})$, $V_{p,1}(s_{p,1})$, $V_{p,w}(s_{p,w})$ and $V_p(s_p)$ are the solution to the household problem outlined in (3.1.2)-(3.2.3) with $c_{y,d}(s_{y,d})$, $c_{y,a}(s_{y,a})$, $c_{p,1}(s_{p,1})$, $c_{p,w}(s_{p,w})$, $c_p(s_p)$, $a'_{y,d}(s_{y,d})$, $a'_{y,a}(s_{y,a})$, $a'_{p,1}(s_{p,1})$, $a'_{p,w}(s_{p,w})$, $a'_p(s_p)$, $tra(s_{p,1})$, $ed(s_{p,1})$ being the associated policy functions.*

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[8]Notice that the total population size is normalized to one. The probability measure thus defines the number of people (or equivalently, the total population share) facing a specific endowment with state variables.

2. The prices r and w solve the firm's problem (25) and (26).

3. The government policies satisfy (27), (28) and (29).

4. Markets for physical capital, labor in efficiency units and the consumption good clear:

$$K = \left\{ \begin{array}{c} \int_{\mathbf{S}_{y,d}} a'_{y,d}(s_{y,d})d\Phi + \int_{\mathbf{S}_{y,a}} a'_{y,a}(s_{y,a})d\Phi \\ + \int_{\mathbf{S}_{p,1}} a'_{p,1}(s_{p,1})d\Phi + \int_{\mathbf{S}_{p,w}} a'_{p,w}(s_{p,w})d\Phi + \int_{\mathbf{S}_p} a'_p(s_p)d\Phi \end{array} \right\} \tag{30}$$

$$L = \left\{ \begin{array}{c} \int_{\mathbf{S}_{y,d}} \varepsilon_j^e \eta^{j,e} d\Phi + \int_{\mathbf{S}_{y,a}} \varepsilon_j^e \eta^{j,e} d\Phi \\ + \int_{\mathbf{S}_{p,1}} \varepsilon_j^e \eta^{j,e} d\Phi + \int_{\mathbf{S}_{p,w}} \varepsilon_j^e \eta^{j,e} d\Phi \end{array} \right\} \tag{31}$$

$$C + [K - (1-\delta)K] + T + I - \Xi = F(K,L) \tag{32}$$

where

$$C = \left\{ \begin{array}{c} \int_{\mathbf{S}_{y,d}} c_{y,d}(s_{y,d})d\Phi + \int_{\mathbf{S}_{y,a}} c_{y,a}(s_{y,a})d\Phi \\ + \int_{\mathbf{S}_{p,1}} c_{p,1}(s_{p,1})d\Phi + \int_{\mathbf{S}_{p,w}} c_{p,w}(s_{p,w})d\Phi + \int_{\mathbf{S}_p} c_p(s_p)d\Phi \end{array} \right\} \tag{33}$$

$$T = \int_{\mathbf{S}_{p,1}} tra(s_{p,1})d\Phi \tag{34}$$

$$I = \kappa(1-\nu) \int_{\mathbf{S}_{p,1}} ed(s_{p,1})d\Phi \tag{35}$$

5. The Aggregate Law of Motion is stationary:

$$\Phi = H(\Phi) \tag{36}$$

The function H is generated by the policy functions $a'_{y,d}(s_{y,d})$, $a'_{y,a}(s_{y,a})$, $a'_{p,1}(s_{p,1})$, $a'_p(s_p)$, $tra(s_{p,1})$, $ed(s_{p,1})$, the Markov process $Q(\eta^e, N^e)$ and the transmission matrix $Q^{initial,e}(i, i \in I = \{1,2,...,n\})$ and can be written explicitly as

(a) For all sets $(\mathcal{A}, \mathcal{A}^p, \mathcal{E}, \mathcal{N}^e, \mathcal{J})$ with $\mathcal{J} = \{2,...,30\}$ such that $(\mathcal{A}, \mathcal{A}^p, \mathcal{E}, \mathcal{N}, \mathcal{J}) \in \mathcal{S}_{y,a}$, the measure of agents whose parents are alive is given by

$$\Phi_a = \int_{\mathbf{S}_{y,a}} P_{y,a}(s_{y,a}, (\mathcal{A}, \mathcal{A}^p, \mathcal{E}, \mathcal{N}^e, \mathcal{J}))d\Phi_a \tag{37}$$

where $P_{y,a}(s_{y,a}, (\mathcal{A}, \mathcal{A}^p, \mathcal{E}, \mathcal{N}^e, \mathcal{J}))$

$$= \left\{ \begin{array}{ll} \psi_{(j+30)} \sum_{\eta' \in \mathcal{N}^e} Q(\eta, \eta') & \text{if } a'_{y,a}(s_{y,a}) \in \mathcal{A}, \ a'_p(s_p) \in \mathcal{A}^p, \ e = e' \in \mathcal{E}, \ j+1 \in \mathcal{J} \\ 0 & \text{otherwise} \end{array} \right.$$

$P_{y,a}(s_{y,a}, (\mathcal{A}, \mathcal{A}^p, \mathcal{E}, \mathcal{N}^e, \mathcal{J}))$ is the transition function. It gives the probability that an agent with endowment $s_{y,a}$ at age j ends up in $j+1$ with asset holdings $a'_{y,a} \in \mathcal{A}$, productivity state $\eta' \in \mathcal{N}^e$ and parental asset holdings $a'_p \in \mathcal{A}^p$. The education level remains constant.

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(b) *For all sets $(\mathcal{A}, \mathcal{E}, \mathcal{N}^e, \mathcal{J})$ with $\mathcal{J} = \{2, ..., 30\}$ such that $(\mathcal{A}, \mathcal{E}, \mathcal{N}, \mathcal{J}) \in \mathcal{S}_{y,d}$, the measure of agents with deceased parents is given by*

$$\Phi_d = \left\{ \begin{array}{c} \int_{\mathbf{S}_{y,d}} P_{y,d}(s_{y,d}, (\mathcal{A}, \mathcal{E}, \mathcal{N}^e, \mathcal{J}))d\Phi_d + \\ \int_{\mathbf{S}_{y,a}} (1 - \psi_{j+30}) P_{y,a}(s_{y,a}, (\mathcal{A}, \mathcal{A}^p, \mathcal{E}, \mathcal{N}^e, \mathcal{J}))d\Phi_a \end{array} \right\} \tag{38}$$

where $P_{y,d}(s_{y,d}, (\mathcal{A}, \mathcal{E}, \mathcal{N}^e, \mathcal{J}))$

$$= \left\{ \begin{array}{cc} \sum\limits_{\eta' \in \mathcal{N}^e} Q(\eta, \eta') & \text{if } a'_{y,a}(s_{y,a}) \in \mathcal{A}, \ e = e' \in \mathcal{E}, \ j + 1 \in \mathcal{J} \\ 0 & \text{otherwise} \end{array} \right.$$

As fraction $(1 - \psi_{j+30})$ of parents dies in period j, Φ_d incorporates the measure of young agents whose parents died in the previous period.

(c) *For all sets $(\mathcal{A}, \mathcal{I}, \mathcal{J})$ with $\mathcal{J} = \{31\}$ such that $(\mathcal{A}, \mathcal{I}, \mathcal{J}) \in \mathcal{S}_{p,1}$, the measure of parent households in $j = 31$ is given by*

$$\Phi_{p,1} = \left\{ \begin{array}{c} \int_{\mathbf{S}_{y,d}} P_{p,1}(s_{y,d}, (\mathcal{A}, \mathcal{I}, \mathcal{J}))d\Phi_d \\ + \int_{\mathbf{S}_{y,a}} P_{p,1}(s_{y,a}, (\mathcal{A}, \mathcal{I}, \mathcal{J}))d\Phi_a \end{array} \right\} \tag{39}$$

where $P_{p,1}(s_{y,d}, (\mathcal{A}, \mathcal{I}, \mathcal{J}))$

$$= \left\{ \begin{array}{cc} \sum\limits_{i' \in \mathcal{I}} Q^{initial,e}(i, i') & \text{if } a'_{y,a}(s_{y,a}) \in \mathcal{A}, \ j + 1 \in \mathcal{J} \\ 0 & \text{otherwise} \end{array} \right.$$

and $P_{p,1}(s_{y,d}, (\mathcal{A}, \mathcal{I}, \mathcal{J}))$ follows straightforwardly.
$P_{p,1}(., (\mathcal{A}, \mathcal{I}, \mathcal{J}))$ shows the transition from child households to parent households. The measure of parent households collects all child households.

(d) *The measure of parent households while working is generated in a similar fashion.*

(e) *For all sets $(\mathcal{A}, \mathcal{A}^p, \mathcal{E}, \mathcal{N}^e, \mathcal{J})$ with $\mathcal{J} = \{1\}$ such that $(\mathcal{A}, \mathcal{A}^p, \mathcal{E}, \mathcal{N}, \mathcal{J}) \in \mathcal{S}_{y,a}$, the measure of agents in their first period is given by*

$$\Phi^{initial} = \int_{\mathbf{S}_{p,1}} P_{p,1}^{initial}(s_{p,1}, (\mathcal{A}, \mathcal{A}^p, \mathcal{E}, \mathcal{N}^e, \mathcal{J}))d\Phi_{p,1} \tag{40}$$

where $P_{p,1}^{initial}(s_{p,1}, (\mathcal{A}, \mathcal{A}^p, \mathcal{E}, \mathcal{N}^e, \mathcal{J}))$ is given by $a'_{p,1}(s_{p,1})$, $tra(s_{p,1})$ and $ed(s_{p,1})$ where $a'_{p,1}(s_{p,1}) \in \mathcal{A}$, $tra(s_{p,1}) \in \mathcal{A}^p$ and $ed(s_{p,1}) \in \mathcal{E}$.

(f) *The measure of agents during retirement is generated by the policy function $a'_p(s_p)$ where $a'_p(s_p) \in \mathcal{A}$.*

A few remarks regarding the equilibrium conditions are in order. (30) and (31) state that aggregate physical capital and labor measured in efficiency units follow from aggregating the respective holdings of each agent and weighting them appropriately. (32) requires that the good market clears, i.e. that the demand for goods, which is shown on the left-hand side,

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is equal to the supply of goods. The term $[K - (1 - \delta)K]$ on the left-hand side determines the amount of investment that is necessary to keep the aggregate capital stock constant, whereas I and T are aggregate college expenditures and transfers in stationary state, respectively. (36) requires stationarity of the probability measure Φ. The function H is the transition function which determines the probability that an agent will end up with a certain combination of state variables tomorrow, given his endowment with state variables today. Notice that the stationarity condition requires that child households are (on average) 'identical' to their parents in the sense that they reproduce their parent household's distribution once they become parents themselves. This in turn implies that the distribution of transfers and inheritances that child households receive is consistent with the distribution of transfers that is actually left by parent households. I present more details about the computational procedure in the appendix.

5 Parametrization and Calibration

I calibrate parameter values of the benchmark economy to represent relevant features of the U.S. economy as closely as possible. It will be assumed that the length of one unit of time in the model economy corresponds to a calendar year. The targets that I choose for the benchmark economy describe the U.S. economy around 1980. I therefore label this benchmark case 'economy 1980'. In order to compare the change of enrolment patterns over time, I define a second steady-state which I denote as 'economy 2000'.

5.1 Economy 1980

5.1.1 Technology, Demographics and Preferences

I assume that the utility from consumption in each period is given by $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$. Production is assumed to follow the aggregate production function $F(K, L) = K^{\alpha}L^{1-\alpha}$. I set the capital share in income (α) equal to 0.36, as estimated by Prescott (1986). Following Imrohoroglu et. al. (1995) and Heer (2001), I assume that capital depreciates at an annual rate of 8 percent. The conditional survival probability ψ_j is taken from the National Vital Statistics Report, Vol. 53, No. 6 (2004) and refers to the conditional survival probability for the U.S. population. Only values between age 53 and age 82 are used. I assume that the survival probability is zero for agents at the age of 83. The survival probability for households that are younger than 53 years is assumed to be equal to 1.[9] The preference parameter γ determines the relative risk aversion and is the inverse relation to the intertemporal elasticity of substitution. I follow Attanasio (1999) and Gourinchas and Parker (2002) who estimate γ using consumption data and find a value of 1.5. This value is well in the interval of 1 to 3 commonly used in the literature.

The two main parameters that govern the accumulation of wealth and transfer behavior - the discount factor β and the intergenerational discount factor ς - are calibrated jointly such

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[9]The actual survival probability before 53 is close to 1. See the National Vital Statistics Report.

that the baseline economy is consistent with the wealth-income ratio and the relative size of intergenerational transfers in the U.S. economy in 1980. Gale and Scholz (1994) compute a ratio of inter vivos transfers to total wealth of 0.28 percent from the 1983 and 1986 Survey of Consumer Finances. This number comprises financial non-college support to children. The resulting ς is 0.7, which implies that for the benchmark economy to be consistent with the transfer flows observable in the U.S. economy, a parent household would have to consider the utility of a child household 30 percent less than it considers its own utility. This is in line with results obtained from Nishiyama (2002) who uses an altruistic framework to explain the observable degree of wealth inequality in U.S. economy.

5.1.2 Earnings Process

I assume that the process that governs the productivity shocks $\eta^{j,e}$ follow an AR(1) process with persistence parameter ρ^{hs} for high school graduates and ρ^{col} for college graduates. The variance of the innovations are σ^{hs} and σ^{col}, respectively. These parameters are estimated by Hubbard et al. (1995)(HSZ in the following) from the 1982 to 1986 Panel Study of Income Dynamics (PSID). They find that high school graduates have a lower earnings persistence and a higher variance ($\rho^{hs} = 0.946$, $\sigma^{hs} = 0.025$) compared to college graduates ($\rho^{col} = 0.955$, $\sigma^{col} = 0.016$). It should be noted that both estimates are rather conservative as HSZ use the combined labor income of the husband and wife (if married) plus unemployment insurance for their estimates. When I approximate the earnings process with a four-state Markov process using the procedure proposed by Tauchen and Hussey (1991), I find that the transition matrices for high school and college graduates are nearly indistinguishable.

I also take the average age-efficiency profile ε_j^e from HSZ, which gives us an estimate of the college premium for different age groups. The authors find that earnings are more peaked for college families, which is in line with findings from other empirical studies. Different from the model estimated by HSZ, we endogenize the college enrolment decision. This implies that in equilibrium, college graduates are more likely to have positive deviations with the respect to the average age profile, because more productive children (measured in terms of their first draw from the productivity distribution) are more likely to attend college. This is not reflected in the estimation of the mean age-earnings profile of HSZ. I thus adjust the age profile for college graduates in the model downwards, such that the average college premium *after* selection coincides in both models.

For the economy 1980, I also adjust their estimates for the earnings variance. The reason is that HSZ estimate their model for the beginning of the 1980's. Parents who decide upon transfers in the beginning of the 1980's accumulated their wealth in the 1970's or even earlier. Gottschalk and Moffitt (1994) find that the variance of both permanent and transitory earnings increased by 40 percent between the two decades. For the economy 1980, I thus use a σ^{hs} of 0.015 and σ^{col} of 0.01.

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5.1.3 College Completion and Cost of College

I assume that the probability of college completion $\lambda(i)$ is an increasing function of the initial productivity state i. In particular, I assume

$$\lambda(i) = d + a(i - 1) \tag{41}$$

$$d, a \geq 0$$

Recall that I approximate the AR(1) process with a 4-state Markov chain; I therefore have a grid with 4 points that represent the different productivity levels. Consequently, the parameter d governs the completion probability for child households with low ability ($i = 1$). d thus governs the expected return associated with college investment. I set d such that the college participation rate of low ability students with parents in the highest income quartile is 0.3. This is also the enrolment share of low-ability children from families in the highest income quartile in the NLSY79 as reported by Belley and Lochner (2007).[10] I use families from the highest income quartile as a calibration target because financial constraints are not very likely to have an impact on their college enrolment decision (Carneiro and Heckman (2002)). Instead, I impose that their decision is solely based on the expected return, which is governed by d. For $d = 0.32$, the benchmark steady-state replicates the enrolment share of high-income families with children of low ability. This implies that these students graduate with a probability of 32 percent.

Two additional parameters influence the college investment behavior, the tuition costs κ and the slope parameter a. I calibrate these parameters jointly such that the model is consistent with an overall dropout probability of 50 percent (Restuccia and Urrutia (2004)) and a fraction of college graduates of 25 percent. I obtain a κ of 0.95 and an a of 0.07. In line with U.S. evidence, the model implies that total college expenses are approximately equal to per-capita GDP (see e.g. Collegeboard (2005) or Gallipoli et al. (2006)). A slope parameter a of 0.07 implies that high-ability children have a 21 percent higher change of graduating from college than low-ability children.

5.1.4 Transmission of Initial Productivity

In the data, there is a high degree of persistence in economic outcomes across generations. Inheritability of genetic traits, the family environment and early education all matter for explaining different levels of pre-college ability levels Restuccia and Urrutia (2004). Following Keane and Wolpin (2001), I assume that the transmission of initial productivity levels depends solely on the level of parental education. Technically, I generate a positive link by assuming that parents transmit part of their productivity shock at age $j = 30$ to their children, who enter the economy when parents turn to $j = 31$.

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[10]Belley and Lochner (2007) use the Armed Forces Qualification Test (AFQT) as a proxy for ability. AFQT test scores are a widely used measure of cognitive achievement by social scientists using the NLSY and are strongly correlated with positive outcomes like education and post-school earnings. See their footnote 2 for further references

Because transmission depends on parental education, I define two separate transition matrices for parents with high school and college education, $Q^{initial,hs}$ and $Q^{initial,col}$. Let $p_{i^p,i^c}^{col} \forall \{1, ..., 4\}$ be an element of the transition matrix of college graduates. Then, p_{i^p,i^c}^{col} is the probability that a college educated parent household of age $j = 30$ is of productivity i^p, while the child receives an initial productivity of i^c. In order to achieve a positive link across generations, it needs to be that $p_{i^p,i^c}^{col} \geq p_{i^p,i^c}^{hs}$ for 'high' levels of i^c and $p_{i^p,i^c}^{col} \leq p_{i^p,i^c}^{hs}$ for 'low' levels i^c. In addition, I require that $p_{i^p,i^c} \geq 0$ to ensure that there are non-trivial percentages in all productivity levels. Moreover, the probabilities in each row of the transition matrix have to sum to 1, $\sum_{i^c} p_{i^p,i^c} = 1$.

Limited by these conditions, I model both transition matrices as linear combinations between an identity matrix and a matrix which rows consist of an additive sequence. For college graduates, this sequence has starting value 0, increment $\frac{(n-1)n}{2}$ and n elements, where n is the number of productivity shocks. Let π be the weight of this matrix and $(1 - \pi)$ the weight of the identity matrix. Then, $p_{i^p,i^c} \geq 0$ requires $\pi \in (0, 1)$. π is calibrated such that the model reproduces the correlation of college education across generations. Data from NLSY 79 reported by Keane and Wolpin (2001), Table 4, suggests that this correlation is between 0.28 and 0.38, depending on the youth's level of completed schooling at age 16. The correlation of education college attainment is significantly weaker if I consider only parent-child pairs for which the children's schooling level at the age of 16 is similar. Since I do not model differences pre-tertiary education, I choose π such that the model implies a correlation of 0.31.

5.1.5 College Subsidies and Taxes

Parents who send their children to college receive a government subsidy $\nu_{|ed=1}(a_{p,1}, \varepsilon_j^e \eta^{j,e} w)$ for each unit of expenditure in college education. The subsidy is a function of current income and asset holdings. In the U.S., the calculation of the subsidy is based on an estimate of the student's family ability to pay the cost of college. This estimate is based on estimates of 'discretionary income' and 'available assets' Feldstein (1995). I approximate discretionary income as the sum of labor and capital income, net of taxes. Available assets are calculated as the difference between current wealth holdings and a wealth level that is deemed to maintain the current standard of living, which I approximate by the average asset holdings in the economy, called $\bar{a}$. These two measures are then combined by adding 12 percent of the available net assets to the discretionary income, see Feldstein (1995).

The key point of the exercise is that every extra dollar of savings raises the amount of available resources, which decreases the subsidy. Feldstein (1995) points out that this indirect savings tax may generate strong disincentives for the accumulation of wealth. For simplicity and because this specification is common in the literature, I assume that the subsidy level is linearly decreasing in the level of parental resources:

$$\nu = \max(\nu_0 - \nu_1(\max(0, a_{p,1} - \bar{a}) + (1 - \tau_w) r a_{p,1} (1 - \tau_w) \varepsilon_j^e \eta^{j,e} w), 0) \tag{42}$$

$$\nu_0, \nu_1 \geq 0$$

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I calibrate ν_0 and ν_1 such that (i) the ratio of college subsidies to total college expenses, the subsidy rate, is 0.4, as reported by the OECD (see Akyol and Athreya (2005), Figure 1) and (ii) the subsidy does not cover more than 50 percent of κ, the total college expenses an individual household has to pay, see Keane and Wolpin (2001). This implies estimates of ν_0 of 0.57 and of ν_1 of 0.1. Following De Nardi (2004), I use a capital income tax rate τ_K of 0.2 and a replacement rate for pension benefits of 0.4. Finally, I adjust the tax rate on labor income τ_w such that the government budget (28) is balanced. This results in a tax rate of 15 percent. The results are summarized in Table 2.

5.2 Economy 2000

I adjust the average college premium, the earnings process and the tuition fees in order to account for the increase in between-group inequality, within-group inequality and the doubling of the college expenses (in real terms, see Collegeboard (2005)). All other parameter values are left unchanged. The college premium increases by 30 percentage points (from 40 percent to 70 percent compared to our benchmark case (see Katz and Autor (1999)).

6 Results

In this section, I analyze the quantitative behavior of our benchmark economy. In particular, I use my model as a measurement tool in order to evaluate to what extend borrowing constraints are binding.

6.1 Economy 1980: How Important are Borrowing Constraints?

In this section, I show that the fraction of households that is borrowing constrained in their college decision is 18 percent, which is substantially higher than what estimates from the empirical literature suggest. Carneiro and Heckman (2002) find that at most 8 percent of the population are borrowing constrained in the short-run sense. I argue that the difference is due to the measurement of long-term factors and the fact that parents are imperfectly altruistic. If I apply their methodology to the data generated by the model, my results are broadly consistent with their findings.

6.1.1 The Fraction of Constrained Households

In order to measure the fraction of constrained young households, I start with an experiment in which I allow parents to borrow up the total college expenses. I implement the loan as a transfer from the government to all parents before they decide on how much to invest in their children. In order to keep its budget balanced, the government in turn collects the resources from the child households. The debt contract takes the form of a redeemable loan, for which the annual redemption sum is fixed and independent of the child household's income.

Now, I 'force' parents to use the loan for their children, either in form of financial transfers or in form of college investment or both. Parents cannot use the additional resources for their

own consumption. It is important to notice that this experiment is equivalent to a scenario where the child households are offered a loan directly, and where they decide themselves whether they want to invest in human capital or in financial assets.[11] If the total loan amount is transferred in form of financial assets, the net present value of the loan is zero by construction.[12]

I find that the second experiment raises the total college enrolment rate to 75 percent, an increase of 18 percentage points relative to the benchmark economy. From this it follows that the presence of borrowing constraints for college education is associated with a decrease in the college enrolment rates of 18 percent relative to an economy where enrolment is dictated solely by the expected value of going to college. This result exceeds the findings from the empirical literature considerably. Carneiro and Heckman (2002) conclude that the fraction of constrained households in the population is at most 8 percent. In the next two sections, I shed further light on the difference between my results and theirs. I show that once I apply their methodology to the data generated by my model, the results broadly coincide.

6.1.2   Enrolment Gap

I now examine how the model compares to the data as regards to enrolment gaps between income groups. For the 1980 economy, I compute the college enrolment rate by family income and ability level. Figure 3 plots the results.

The empirical counterpart is taken from Belley and Lochner (2007), Figure 2a, who study data from the NLSY79. Figure 4 shows their results. I find that - both in the model and in the data - college enrolment increases with ability level. In the model, this is an immediate consequence of the assumption that more able children have a higher likelihood to graduate from college, which makes college investment more profitable for their parents.

These plots also indicate a subsidiary, but quantitatively important role for family income in accounting for college entry, which one might think of as indicating the importance of borrowing constraints. In an influential paper, Carneiro and Heckman (2002) claim that enrolment gaps with respect to family income are not very informative about the strength of borrowing constraints. They argue that one needs to distinguish between short-term borrowing constraints, which are created by short-term cash-flow problems when a child is on the threshold of college enrolment, and long-term borrowing constraints related to a family's ability to finance education through a youth's childhood. Only the short-term constraints are of relevance for public policy in my framework, as they can be addressed directly with policy measures such as a different college subsidy scheme. Family income, which is measured when the child is on the threshold of college entry, thus captures short-term as well as long-term constraints.

Carneiro and Heckman control for long-term factors by including parental education and a set of other family related variables in addition to a measure of academic ability when

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[11]Because parents choose the optimal mix between financial transfers and college investment such that they maximize their own utility and their children's utility is part of their total utility, the parental decision about the optimal division of the loan coincides with the decision the offspring would take.

[12]I expect that low-ability children receive a greater share of the loan in terms of financial transfers.

computing the enrolment gaps. They find that gaps in college entry by family income narrow significantly after controlling for long-run borrowing constraints (see Figure 5 in their paper).

In Table 5, I report the enrolment gaps with respect to the highest income quartile generated by the baseline economy. Each column represents a different ability quartile. Panel A of Table 5 documents the enrolment gaps corresponding to Figure 3. Panel B and C give the enrolment gaps after controlling for the parental education level (high school or college, respectively).

In line with Carneiro and Heckman (2002), I find that enrolment gaps narrow after controlling for long-term factors, in my case ability and parental schooling. Table 5 reveals that enrolment gaps for children from college graduated parents differ very little across different income groups.

Carneiro and Heckman (2002) interpret these enrolment gaps as the fraction of the population that cannot attend college because of financial constraints. They conclude that at most 8 percent of the population is constrained in their college decision. I repeat their analysis and weight the enrolment gaps documented in Table 5 with the fraction of the total population in the respective ability and income quartile. I find that the maximum fraction constrained is 14 percent if I condition on high school education (Panel B) and 11 percent if I control for college education (Panel C). Without controlling for education, the estimated share would have been considerably higher (20 percent, panel A) which confirms that incorporating long-term factors decreases the conjectured role of borrowing constraints, as argued by Carneiro and Heckman (2002).

Above I argued that removing the borrowing constraint for college enrolment leads to an 18 increase in the enrolment rate. Thus, the model-based estimate of the extent to which borrowing constraints adversely affect college entry is substantially higher than the econometric estimate derived from controlling for long-term factors. I will now show that this disparity is due to imperfect altruism on the part of parental households which implies that young and able households may receive insufficient transfers even if their parents could afford to send them to college.

6.1.3 The Role of Imperfect Altruism

In order to gauge the importance of imperfect altruism, I repeat the experiment from Section 6.1.1 but let parents decide how to spend the additional resources provided by the government. Thus, comparing this experiment to the 'forced' experiment reported in Table 4, allows me to check how imperfect altruism affects the extent of borrowing constraints for prospective college entrants. I will refer to this experiment as 'free disposal'. The fact that parents are imperfectly altruistic implies that parents weight the disutility the child suffers from repaying the loan less than their utility gain they obtain by using part of the loan for their own consumption purposes. I thus expect that parents do not provide the total loan amount to their children.[13] The 'free disposal' experiment therefore mainly illustrates the

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[13]Because of imperfect capital markets, parents might also be borrowing constrained for their own consumption purposes. Since parents are already in an advanced stage of the life cycle when transfers take place, I do not expect constraints on parental consumption to be binding for a larger fraction of families.

extend to which imperfect altruism biases our measured fraction of constrained families.

Table 4 reports the total share of students that engage in college education. I find that the fraction of college students in each cohort increase from 57 percent to 62 percent when I allow for borrowing. Compared to the increase of 18 percent that one could observe in the 'forced' experiment above, this share appears to be relatively small.

In order to understand the differences, it is interesting to compare the Figures 3, 5 and 6. I find that in the experiment with 'forced' credit (Figure 6), the enrolment rates increase not only for households from the lower end of the income distribution, but also for rich households. I do not observe this pattern in the 'free-disposal' experiment (Figure 5), which suggest that enrolment rates rise because the 'forced' experiment eliminates all effects of imperfect altruism. Hence, ignoring the possibility of *imperfect* altruism may bias the estimated fraction of constrained households downwards. The results show that, even though the average enrolment gap measured in the model is in line with empirical results by Carneiro and Heckman (2002), the true fraction of constrained households is much larger as even children from high-income family may not receive the sufficient amount of transfers needed to go to college.

6.1.4   The Role of Parental Education as a Long-Run Factor

Conditioning on parental education has a significant impact on observable enrolment patterns, implying that there is a strong link between parental education and children's college attendance. Apart from the fact that college graduated parents are richer, they also have, by assumption, smarter children.

However, Table 6 documents that even after controlling for ability and family income quartile, offspring from college educated families have a 4.7 percent higher change of being enrolled in college than descendants from high school educated families (Table 6, first row). This difference stems from the fact that education not only determines the level of family income but also the level of parental wealth. In the empirical literature, family income is usually solely observed in a specific year. Wealth in turn is determined by permanent income, which may only be weakly related to the level of income around college age.

The second row of Table 6 accounts for this effect. Here, I compute the average difference between the enrolment rates of college graduates and high school graduates, controlling for the quartile of family income, ability and assets. The results of the first and the second row are extremely similar, suggesting that differences in asset holdings - after controlling for family income - do not explain the gap in college enrolment between children of differently educated parents.

The findings contribute to the debate in the literature on whether parental education should be used as a measure for long-term borrowing constraints (Carneiro and Heckman (2002), Kane (2006)). To the extent that parents can help financing their children's education with current income or accumulated assets, conditioning on parental education may lead to an understatement of the role of short-term constraints (Kane 2006, p. 1394). The results suggest that this is not the case; parental education seems to have an influence on college going, which is independent of the wealth effect.

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Neither differences in parental endowment nor differences in children's ability explain fully why high school educated parents provide less support for their offspring's college education. Instead, the differences stem from different expectations about the future. High school graduates are exposed to a higher earnings risk and lower average earnings, even after the time their children left home. Indeed, I find that high school graduates have higher savings than college graduates at age 53, the age at which parent households decide about transfers.

In Tables 7 and 8, I compute average savings for different ability, income and wealth quartiles, differentiated by the education level of the household. The results convey a clear message: high school graduates at age 53 tend to save more than college graduates at this age.

Thus, in conclusion, I find that large fraction of borrowing constrained households measured in my model compared to the literature can be explained by (i) the fact that parents are imperfectly altruistic, which implies that even children from high-income families may not receive enough parental funding and (ii) the high school educated parents save more and transfer less than their college educated counterparts, even if their children are equally well prepared for college.

6.2 Economy 2000: Have borrowing constraints become more limiting?

6.2.1 Have Borrowing Constraints Become more Limiting?

In order to analyze to what extent borrowing constraints have become more binding as the economic environment changed between 1980 and 2000, I repeat the 'free-disposal' as well as the 'forced' experiment for the 2000 economy. The 'free-disposal' experiment for the economy 2000 indicates that the share of college students increases from 60 percent to 85 percent, which is a change of 25 percentage points (see Table 4). This result is in stark contrast to the result for the economy 1980, for which enrolment increased by only 5 percentage points.

Comparison of the college enrolment rates for the tow different economies, see Figures 5 and 9 reveals that the low-ability students make the difference. While these agents' college enrolment decisions are approximately unaffected by the provision of loans in the 1980 economy, this policy increases their enrolment rates significantly in the 2000 economy. This indicates that – due to the increase in the college premium – college education becomes more profitable for this group of students. As indicated by the enrolment patterns in the previous section, only rich parents are willing to take advantage of this and invest in their low-ability children. Despite the surge in the college premium, parents with lower income, instead, do not find it advantageous to transfer sufficient funds to their offspring.

Applying the 'forced' credit experiment to the economy 2000 reveals the full extent to which lack of parental transfers (and thus borrowing constraints) limit college enrolment. In this alternative experiment, enrolment goes up to approximately 100 percent. That is, around 40 percent of the population are constrained in their college decision, compared to

18 percent in the economy 1980.[14]

Thus, the recent changes in the economic environment in the U.S. generate a larger fraction of constrained households. In order to understand why, I present the changes in the enrolment patterns between 1980 and 2000 in the next section.

6.2.2 Enrolment Rates

I now analyze to what extend the increase in the college premium, the tuition fees and the variance of the productivity process have affected the college enrolment for different ability and family income quartiles. Figure 7 shows the enrolment rates obtained from our model economy 2000, while the empirical counterpart from the NLSY97 is displayed in Figure 8 (see Belley and Lochner (2007), Figure 2b). In line with their observations, I find that the role of ability did not change with respect to the economy 1980. Also consistent with the data, there are two striking differences between the economies of 1980 and 2000:

1. Enrolment rates are higher for the economy 2000. This suggests that in the aggregate, the rise in the rate of return on tertiary education more than outweighs the increase in risk and the higher price of tuition.

2. Enrolment gaps between different family income groups have widened over time, in particular for the low-ability students. This holds even after controlling for parental education (see Table 10).

To better understand the increase in the enrolment gap for low-ability students, I compute the share of college students from the lowest ability for the economy 1980 and the economy 2000. I find that this fraction has more than doubled from 1.8 percent to 5 percent (see Table 4). This increase could indicate that the number of high income families with low ability children rose since high income families are more prone to send their offspring to college. However, our results reveal that the number of families from the top income quartile that have children with low ability actually declined from 2.4 to 1.3 percent. Consequently, the rise of the fraction of low-ability college students must be due to the increase in the college premium which made college investment more attractive, even for low-ability students.

Next, I compute the average savings for different income, wealth and ability quartiles, using the policy functions and the steady-state distribution of agents generated by our economy 2000 for agents at age 53. The results are shown in Tables 10 and 11. If I compare the difference between high school and college graduates for 1980 (tables 7 and 8) with the differences in 2000, I find that high school graduated parents now save even more compared to their college graduated counterparts, all other things equal. The increase appears to be more pronounced for parents with children in the lowest ability quartile.

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[14]It is also interesting to note that the model implies that the share of students who drop out from college without a degree increased, albeit only slightly, when one compares the baseline economy to the economy 2000. This rise is an immediate consequence of the fact that the share of low-ability students increased. The findings thus provide an explanation for the changing dynamic between college enrolment and college completion, which is documented by Turner (2004). See Table 4

Strikingly, savings of high school graduates relative to college graduates increases, after controlling income and wealth. This is due to the increase in the variance of earnings shocks, which I use in order to simulate the increment in the within-group inequality. This rise in uncertainty has a stronger impact on high school graduates, as labor earnings comprise a bigger share of total income for that group. Therefore, the need for precautionary savings is higher for the high school group, which causes them to keep more resources to secure their own future. This result is reinforced by the fact that high school graduated parents are more likely to have low-ability children, which reduces the expected return from investing. In addition, the rise in tuition fees has made college expenses even more expensive, reducing the incentives for the poor to invest in their children.

In conclusion, I find that the recent changes in the economic environment generate a stronger link between family income and college enrolment in the model, which is in line with the data. The model predict that financial constraint have become more limiting over the course of time. In the model, this stems from the fact that the rise in the college premium implies that more young household are willing to go to college. Only the rich parents, however, can take advantage of this and invest. The others are hampered by the increase in within-group inequality, which requires more savings for their own future, and the increment of the tuition fees.

6.3 Testable Implications

A key insight from the analysis above is that, according to my model, parents at age 53 with high school education save more and transfer less to their offspring than college graduates at the same age. I will now examine to empirical relevance of this aspect of my analysis. I address this issue by computing education specific savings and transfers from the 1986 Survey of Consumer Finances (SCF).

6.3.1 The Trade-Off between Transfers and Savings in the Data

The SCF is a household survey conducted on a triennial basis. It consists of a cross-section of U.S. households, with the exception of the waves in 1983 and 1986 which contain repeated cross-sections. This allows me to observe household savings between 1983 and 1986. Moreover, the 1986 wave also ask extensively about household's transfer behavior, and has therefore become a standard reference with respect to parental inter-vivos transfers (see e.g. Gale and Scholz (1994)). I compute total transfers given by a household as the sum of all monetary transfers and college expenses, which are reported separately in the SCF.[15] I use savings in constant prices accumulated between 1983 and 1986. In order to be consistent with the model, I only consider those households that are between 45 and 65 years old, and that have at least one child. As Table 12 shows, college graduates have on average higher savings and transfer more resources (column 1), as one would expect from the fact that college graduates are on average more affluent and have higher income than high school

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[15]The 1986 SCF only reports transfers if the transfer amount is above 3000 US-Dollar.

graduates. However, if I introduce dummies for the asset quartile and the income quartile in order to control for wealth and income effects, I find that college graduates make more transfers, but they save considerably less than high school educated parents.[16] In line with the predictions of the model, this suggests that there is trade-off between savings and transfers, and that the split between the two is also determined by expectations about the future. This finding has important implications for the design of college subsidy rules. Dynarski and Scott-Clayton (2006) and Kane (2006) argue that part of the enrolment gap can be explained by the complexity of existing system of distributing federal student aid, which disproportionately burdens youth from low-income and low-education families. They propose to implement simple, easily communicable aid programs. My results extend their argument: because financial aid is determined solely on the basis of actual family wealth and income, it adversely affects students from low-income families. Instead, college aid should also be based on expected future earnings.

6.3.2 The Drop in the Degree of Education Persistence

Another model implication that deserves further attention can be seen in Table 4. In the last column, I document the intergenerational correlation of educational attainment for the different economies. Interestingly, the results indicate that the degree of education persistence *decreased* as one moves from the economy 1980 to the economy 2000. This is perhaps surprising as the literature generally assumes that borrowing constraints lead to a *higher* degree of persistence, not the other way round (see Keane and Wolpin (2001), among others).

The fact that the link between parents and children in educational achievement weakened over time can also be seen from Table 6. Comparing the first and the second column, one finds that the role of parental education in predicting college entry declined over time, after controlling for ability, parental wealth and income. This is in line with recent empirical evidence. Both Ellwood and Kane (2000) and Belley and Lochner (2007), Table 3, show that the correlation of parental education and children's college attendance declined over time. They also include a proxy for academic ability in the regression, and control for the parental wealth and income quartile.

The decrease in the role of parental education in predicting college access stems from the fact that more high school educated parents are among the group that are able to afford to send their children to college. While the fraction of high school graduated parents that were either in the top three income quartiles and in the top three wealth quartiles of all parents was 53 percent in 1980, this fraction increased to 56 percent in 2000. This effect must be due to the increase in the instability of earnings, which raises wealth inequality among high school graduates.

This shows that the rise in precautionary savings can simultaneously explain the increase in the number of constrained households *and* the decline in the degree of the intergenerational persistence of education. On the one hand, precautionary savings decrease the willingness of parents to transfer resources to their offspring, leading to a greater fraction of constrained

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[16]The 1986 SCF does not include any measure for the academic ability of the offspring. However, one can show that the key predictions of Tables 7 and 8, still holds, even if one controls only for income and wealth

children. On the other hand, the increment in savings throughout the life cycle increases the fraction of high school graduated parents that possesses the necessary amount of resources to invest, which weakens the intergenerational correlation of education.

7   Conclusion

The aim of this paper is to shed more light on the role of borrowing constraints in determining college enrolment. I also address the question to what extend the quantitative importance of borrowing constraints has changed over time. I propose a dynamic general equilibrium model with overlapping generations, in which households are organized into dynasties. Because of market incompleteness, borrowing against future earnings is not possible, which allows me to measure the fraction of households constrained in their college decision. Young households need to rely on parental transfers and public subsidies if they wish to attend college. A key feature is the assumption that parents provide transfers to their children because of altruism, that is, they consider their children's utility in their own maximization problem.

I calibrate the model such that it is consistent with key parameters of the U.S. economy. Once I increase the college premium, the tuition fees and the earnings inequality in order to simulate changes in the economic environment that occurred between 1980 and 2000, I find that the model is consistent with a rise in the enrolment gaps by levels of family income that are observed in the U.S. data (Belley and Lochner (2007)).

The assumption of one-sided altruism implies that parents face a trade-off between making transfers and saving resources for future consumption, since the parent households have no access to the future returns of the college investment. I find that the transfer flows generated by the model imply that parents are imperfectly altruistic. That is, parents weight their children's utility less than their own. From the point of view of a parent household, this lowers the expected return from investing in their children's education. I find that even youth with rich parents may thus be constrained in their college going decision.

The model also predicts that - all other things equal - high school educated parents transfer less to their children and save more for their own future consumption than college educated parents. In the model, this is due to the fact that high school graduates foresee lower future earnings and higher uncertainty about the actual realization of the earnings process than college graduates. This forces them to save more to secure their own future consumption. I test this prediction using transfer and savings data from the 1986 Survey of Consumer Finances. The results support the predictions of the model: high school graduates transfer less and save more than their college educated counterparts, after controlling for wealth and income.

The model is in line with the fact that parents and children make distinct choices regarding children's schooling may lead to substantial downward biases in estimating the fraction of borrowing constrained household. The model predicts that in 1980, before the economic changes occurred, around 18 percent of all households are financially constrained in their college decision. This is in sharp contrast to empirical evidence based on the NLSY79, which finds that the fraction of constrained households is at most 8 percent (Carneiro and Heckman

(2002)). My results show that narrow enrolment gaps (after controlling for long-term factors) are consistent with a large fraction of households constrained in their college decision.

The model further predicts that the share of families that are financially constrained in their college decision has risen dramatically over time. I document that this stems from the fact that the profitability of college education for low-ability students increased, but their parental willingness to provide resources did not keep pace with that. Parents with lower education levels, who are more severely affected by the increase in the within-group inequality, need more resources to secure their own future and are therefore not willing to provide more financial assistance. Again, this result stresses the importance of considering the determinants of parental transfers for analyzing college enrolment patterns.

The results of this paper have important implications for the design of college subsidies. First of all, the findings suggest that the parental decision to transfer funds necessary for college attendance are not only the current level of family resources but are also based on expectations about the future. This implies that college subsidy rules should not only rely on current information but also consider future events. While it might be difficult to predict the future income stream, the computation of public funding should at least incorporate future expenditures that are already predictable. For example, families that expect to send more than one child to college in the near future should receive more subsidies already for the first child. According to the trade-off described in the model, households anticipate the future expenditure and provide fewer resources already to the first child. Well-designed college subsidies have to compensate for that.

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8 Appendix: Solution Algorithm

I solve the quantitative model using a nested fixed point algorithm with a successive approximation to the value function at its center. The outer loop searches for a fixed point in the interest rate, while the inner loop solves the dynamic program given by (6) - (16) using successive approximation to the value function. Notice that the inner loop is necessary because the hybrid model nests both the pure life cycle economy and a model with infinitely lived dynasties as special cases: the parental value function (21) contains the discounted future utility of the child and vice versa. I start with a guess for the parental value function, $V'_{p,1}$, solve the child's problem (9), giving $V'_{p,1}$ and compute an update for (21), $V''_{p,1}$. I continue iterating over (21)until convergence is achieved.

8.1 Approximating the Value Function

The model economy contains up to two continuous state variables, namely own assets and parents assets, the latter only if parents are alive. [17] Approximating the value function by means of discretization thus proves to be infeasible. Instead, I compute a linear approximation to the value function. I start with a discrete approximation D to the continuum of all possible asset holdings, $\{d_1, d_2, ...d_m\} \equiv D$. The value function is computed at all $d_i \in D$. By means of a simple grid search, I pick that element that gives the highest value of the value function, which I call d_{i^*}. The maximum is bracketed by d_{i^*-1} and d_{i^*+1}. To compute the optimal savings decision, I perform a golden section search on the interval spanned by the two boundary values. In-between values are computed by linear interpolation using d_{i^*-1}, d_{i^*+1} and d_{i^*}. For young agents with living parents, I span a two dimensional grid and use bi-linear interpolation.

This procedure has the advantage that is does not require the value function to be differentiable. Non-differentiabilities may arise because college investment is discretionary. In model period $j = 31$, only parents who are rich enough invest in their offspring's education, which induces a kink in the parental value function. This may also lead to convex parts in the curvature of the value function. Concavity, however, is a necessary prerequisite for the golden section search, which guarantees that the procedure actually picks a global maximum.

We achieve convexification by making the process of college skill accumulation probabilistic. In addition, parents do not only use education investment but also financial transfers in order to transfer resources across generations. Because financial transfers are perfectly divisible, they contribute to convexifying the parental value function. Intuitively, the divisibility of financial transfers allows parents to balance the total amount of resources transferred to the child. If college investment becomes profitable from a certain wealth level onwards, financial transfers are reduced, which causes the value function to increase only slightly. This helps to smooth out the kink introduced by the discrete nature of college investments.

The same argument applies to the savings of a parent household in model period $j = 31$. Parental savings increment parental wealth holdings, which are part of the child household's

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[17]Since we approximate the income process with a Markov chain, all other state variables are discrete.
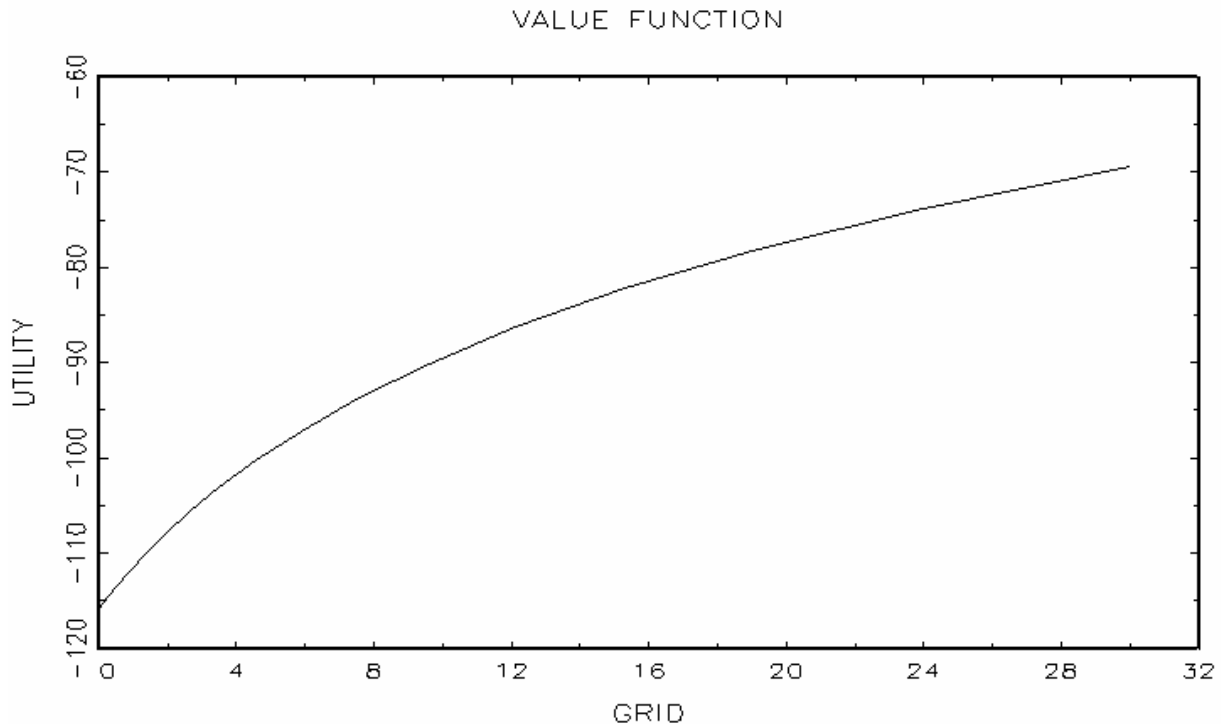
VALUE FUNCTION

Figure 2: Interpolated value function for different levels of household wealth, after controlling for education, productivity and children's ability shock

state space. Because parents decide about savings, monetary transfers and college investment simultaneously given their budget constraint in $j = 31$, investing in college thus reduces their savings and decreases the child households utility.

In total, when computing the approximation to the value function, I find that appears to be concave, as graph 2 shows. [18]

Since the state space involves two continuous variables for the case of agents with living parents, this procedure requires a bilinear interpolation. While linear interpolation is shape preserving, bilinear interpolation is generally not, as outlined in Judd (1998), Ch. 6. In order to avoid potential drawbacks of using an interpolation scheme which is not shape preserving, I use the fact that one of the continuous state variables is exogenously given. That is, when the policy functions for young agents are computed, their parental capital stock is fixed, and I compute $a'_j(a^1, \overline{a}^p, ..)$, $a'_j(a^2, \overline{a}^p, ..), ...,$ by iterating over the capital grid. This implies that while computing the maximum, I only interpolate in one dimension and the problem remains concave. In order to save computation time, I exploit the fact that the value function is monotone increasing function of assets.

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[18]This is not due to the approximation procedure, as linear interpolation is shape preserving.

8.2 Computation of the Equilibrium

Using the policy functions which were computed previously, I can now solve for the equilibrium allocation. Computing an equilibrium involves the following steps:

1. Choose the policy parameters, that is, determine the social security replacement rate rep, the tax rate for capital income τ_k and a college subsidy rule ν.

2. Provide an initial guess for the aggregate (physical) capital stock K_0, the aggregate human capital stock H_0 and the labor tax rate τ_w. Given the guesses for K and H, use the first-order conditions from the firms problem to obtain the relative factor prices r and w.

3. Compute the optimal decision rules as outlined in the previous section.

4. Compute the time invariant measure Φ of agents over the state space.

5. Compute the aggregate asset holdings K_1 and the new human capital stock L_1 using (30) and (31). Given K_1 and L_1, update r, w and τ_w.

6. If $m = max(\left(\frac{K_1-K_0}{K_1}, \frac{L_1-L_0}{L_1}\right) < 10^{-3}$ stop; otherwise return to step 2 and replace K_0 with K_1 and L_0 with L_1.

   In step 4, I find the time-invariant measure of agents Φ by iterating on the aggregate law of motion as defined in (36), as it is commonly done in models with an infinite time horizon. In the model, the measure of parents in their fist period of adulthood depends on the transition of children (because all parents were children one period before). In turn, the measure of children in their first period of life depends on the measure of their parents (because children receive transfers and education). Stationarity requires that the probability measure is constant over time. This implies that, for a given measure of parents, the measure of children exactly reproduces the measure of their own parents.

   I approximate the measure of agents by means of a probability density function. [19] The density function is computed and stored on a finite set of grid points. Following Ríos-Rull and of Minneapolis Research Dept (1997), I choose a grid $D^{density}$ which is finer than the one used in the previous step for computing the decision rules, that is $D \subseteq D^{density}$. Choosing a finer grid for the density increases the precision with which the aggregate variables are computed, since the optimal asset choices are continuous.[20] Thus, the optimal choice will

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[19]Heer and Maußner (2005) argue that approximating the time-invariant measure of agents with the help of a density function saves up to 40 percent of the CPU time with respect to an approximation using the distribution. This is because computing the distribution function requires to compute the inverse of the policy function.

[20]The gains in precision (as measured by aggregate excess demand) by doing so are enormous. The reason is that the aggregate good market clearing condition is just a weighted average of the individuals' budget constraints, where the weights are derived from the grid points of the density Φ. The finer the grid in Φ, the better will be the correspondence between the optimal policies and the resulting weights, leading to better aggregation results.

almost surely be off-grid. In order to map the optimal choices onto the grid, we introduce some kind of lottery. An individual with asset choice $a'(.) \in (a_i, a_{i+1})$ is interpreted as choosing asset holdings a_i with probability λ and asset holdings a_{i+1} with probability $(1 - \lambda)$ where λ solves $a'(.) = \lambda a_i + (1 - \lambda)a_{i+1}$. No lottery is needed for agents for which the lower bounds on asset holdings is binding, which is the case for a positive fraction of the population. I thus allocate the grid points such that there closer mashed in the neighborhood of the lower bound. This is achieved by choosing a grid points which are equally spaced in logarithms. I select the upper bound of $D^{density}$ and D such that it is never found to be binding.

I find the time invariant measure of agents Φ by iterating on the aggregate law of motion as defined in (36). Φ is is only stored on a finite grid, an individual with choice $a'(.) \in (a_i, a_{i+1})$ is interpreted to choose asset holdings k_i with probability λ and asset holdings k_{i+1} with probability $(1 - \lambda)$ where λ solves $a'(.) = \lambda a_i + (1 - \lambda)a_{i+1}$. That is, we compute a piecewise linear approximation to the density function.

The forward recursion starts with an initial distribution of young agents in model period $j = 1$, $\Phi_1(A \times P_r \times A^p \times E \times \{1\})$. This requires an initial guess for the distribution of parents in model period $j = 31$. Using decision rule, one can then derive $\Phi_1(A \times P_r \times A^p \times E \times \{1\})$. In stationary equilibrium, this distribution needs to be identical with $\Phi_{31}(A \times P_r \times \{j = 31\})$, the distribution of agents in model period $j = 36$. Following Heer (2001), a uniform distribution is taken as an initial guess for $\Phi_{31}(A \times P_r \times \{j = 31\})$. The age-independent time-invariant distribution is computed using the decision rules derived from (6)-(16), where $\Phi_{31}(A \times P_r \times \{j = 31\})$ is updated until convergence.

As a check on the internal consistency, aggregate consumption, investment, transfers and output are computed in order to ensure that the good market clearing condition (32) is approximately satisfied.[21]

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[21]Excess supply is typically less than 0.4% of total output.

9   Appendix: Graphs
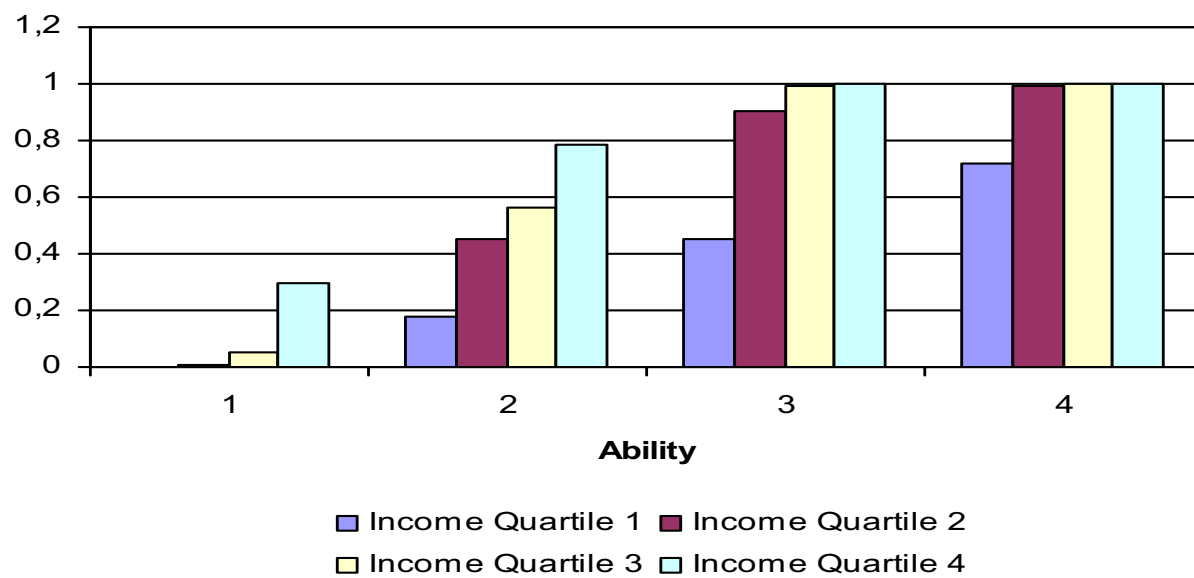
Figure 3: Enrolment Rates 1980
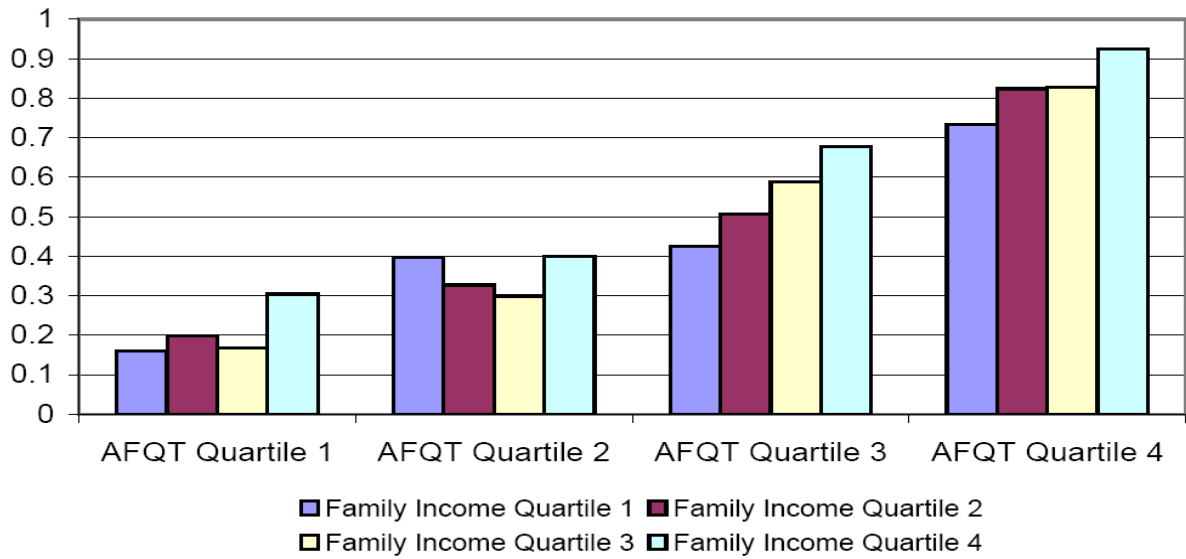
Figure 4: Enrolment Rates NLSY79 (Belley and Lochner (2007), Figure 2a)

Figure 5: Enrolment Rates Economy 1980, parents borrow.

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Figure 6: Enrolment Rates Economy 1980, children borrow

Figure 7: Enrolment Rates 2000
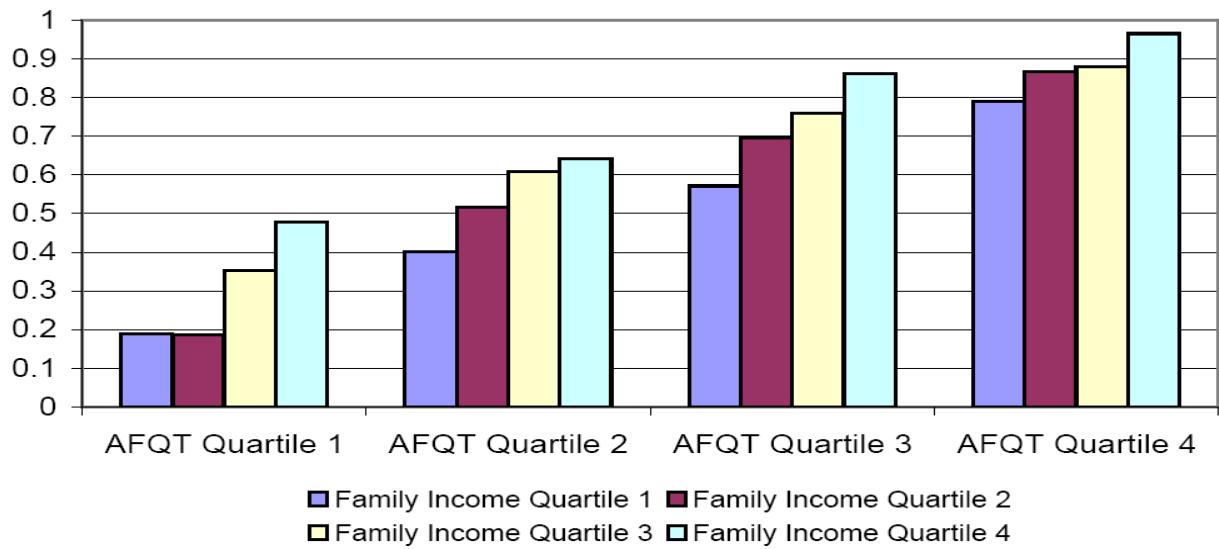
Figure 8: Enrolment Rates NLSY97 (Belley and Lochner (2007), Figure 2b)

Figure 9: Enrolment Rates Economy 2000, parents borrow.
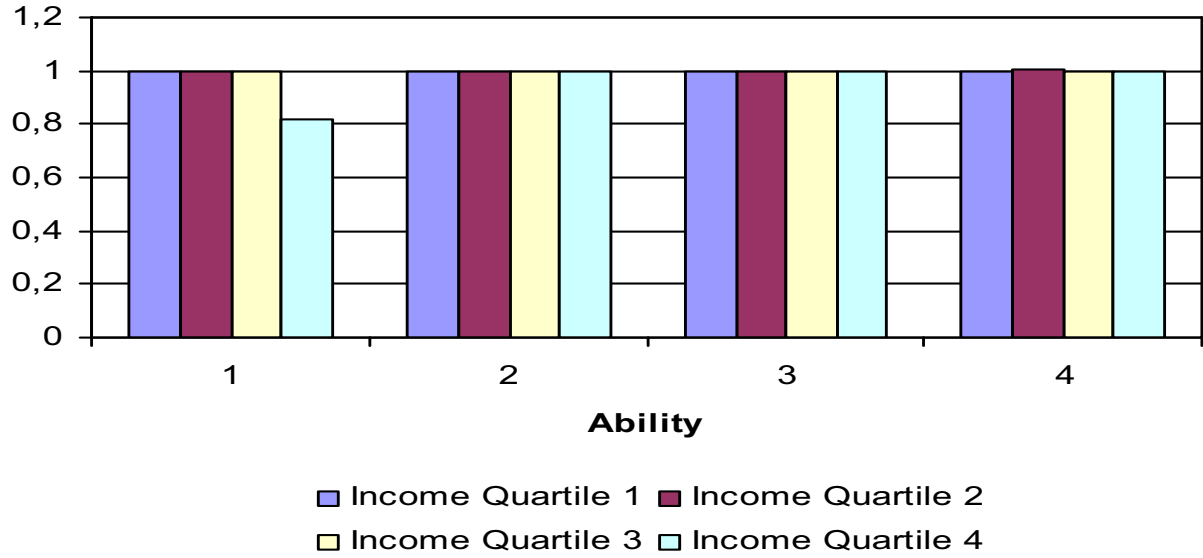
Figure 10: Enrolment Rates Economy 2000, children borrow.

10 Appendix: Tables

Parameter	Description	Value
α	capital share of income	0.36
δ	capital depreciation rate	0.08
γ	risk aversion	1.5
ρ^{hs}	earnings persistence high school	0.946
σ^{hs}	variance shocks	0.015
ρ^{col}	earnings persistence college	0.955
σ^{col}	variance shocks	0.010
τ_K	capital income tax rate	0.2
rep	replacement ratio pensions	0.4

Table 1: Calibrated Parameters with Direct Empirical Counterpart for 'Economy 1980'

Parameter	Description	Value	Target	Target Value
β	discount factor	0.963	Wealth/Income	3.0
κ	cost of college	0.94	% coll. graduates	25
d	college completion rate for low-ability students	0.32	corresponding target in NLSY79	0.3
a	increment of college completion with ability	0.07	overall college completion rate	0.5
π	transmission initial productivity	0.83	intergenerational education persistence	0.3
τ_w	labor income tax	0.15	budget balanced	–
ς	intergen. discounting	0.7	financial transfers/wealth	0.028
ν_0	upper bound coll. subsidy	0.57	upper bound in data	0.5
ν_1	slope coll. subsidy	0.1	coll. subsidies/coll. expenses	0.4

Table 2: Parameters Without Direct Empirical Counterpart

Parameter	Description	Value 1980	2000
σ^{hs}	variance shocks	0.015	0.025
σ^{col}	variance earnings shocks	0.01	0.016
κ	cost of college	0.94	2.13

Table 3: Parameters characterizing the Economy 2000

Table 4: *Enrolment Characteristics for Different Economies*

Economy	% enrolled	% drop out	% low ability	% corr. edu
1980	57	55	1.8	0.30
'free-disposal'	62	55	1.3	0.28
'forced'	75	56	8	0.22
2000	60	56	5	0.28
'free disposal'	85	57	16	0.18
'forced'	99	58	25	0.10

Notes: The Table shows the total enrolment rate, the total drop-out rate, the fraction of college students from the lowest ability quartile, and the intergenerational persistence of college education

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Table 5: *Enrolment Gaps with Respect to the Top Income Quartile for Different Ability Quartiles, Economy 1980*

	Ability Quart. 1	Ability Quart. 2	Ability Quart. 3	Ability Quart. 4
		Panel A – All Parents		
income 4-1	0.29	0.61	0.55	0.28
income 4-2	0.29	0.33	0.09	0.005
income 4-3	0.24	0.22	0.003	0
		Panel B – High School Educated Parents		
income 4-1	0.23	0.45	0.54	0.28
income 4-2	0.23	0.18	0.1	0.007
income 4-3	0.18	0.09	0.002	-0.002
		Panel C – College Educated Parents		
income 4-1	–	–	–	–
income 4-2	0.86	0.06	-0.002	0
income 4-3	0.79	0.06	0	0

Notes: Enrolment gaps are computed for different ability quartiles, without controlling for parental education (panel A), only for children with high-school graduates parents (panel B) and for children with college graduated parents (panel C). An entry for 'income 4-1' of 0.29 indicates that the enrolment rate in the lowest income quartile is about 30 percentage points below the enrolment rate of the highest income quartile. A missing entry (–) indicates that there are no children with parents in this category.

Table 6: *Difference in College Enrolment Rates of College Graduated Parents vs. High School Graduated Parents*

	Economy 1980	Economy 2000
(a)	4.5	2.3
(b)	4.3	2

Notes: In (a), I control for the ability and income quartile and in (b) for ability, income and the wealth quartile. A value of '4.5' indicates that within this group, children with college educated parents are 4.5 percent more likely to enrol in college than youth from high school educated families.

Table 7: *Economy 1980: Average savings of high school graduates (model period $j = 31$), controlling for their wealth and income quartile, and the ability quartile of their children.*

		Ability 1	Ability 2	Ability 3	Ability 4
Wealth 1	Income 1	1.66	1.59	1.50	1.43
	Income 2	2.0	1.90	1.69	1.61
	Income 3	2.27	2.17	2.08	2.08
	Income 4	-	-	-	-
Wealth 2	Income 1	3.19	3.09	2.92	2.77
	Income 2	3.51	3.27	3.05	3.05
	Income 3	3.43	3.43	3.43	3.43
	Income 4	-	-	-	-
Wealth 3	Income 1	4.63	4.63	4.51	4.27
	Income 2	4.51	4.29	4.08	4.08
	Income 3	4.97	4.85	4.80	4.92
	Income 4	-	-	-	-
Wealth 4	Income 1	5.20	5.20	5.20	5.20
	Income 2	6.55	6.55	6.56	6.57
	Income 3	6.94	6.87	6.88	7.05
	Income 4	8.69	8.65	8.72	9.01

Table 8: *Economy 1980: Average savings of college graduates (model period $j = 31$), controlling for their wealth and income quartile, and the ability quartile of their children.*

		Ability 1	Ability 2	Ability 3	Ability 4
Wealth 1	Income 1	-	-	-	-
	Income 2	1.81	1.52	1.50	1.50
	Income 3	2.01	1.94	1.93	1.93
	Income 4	2.09	2.16	2.19	2.20
Wealth 2	Income 1	-	-	-	-
	Income 2	2.62	2.28	2.26	2.26
	Income 3	3.23	2.95	3.02	3.07
	Income 4	2.53	3.11	3.39	3.52
Wealth 3	Income 1	-	-	-	-
	Income 2	-	-	-	-
	Income 3	4.33	4.27	4.26	4.26
	Income 4	3.69	4.27	4.53	4.85
Wealth 4	Income 1	-	-	-	-
	Income 2	-	-	-	-
	Income 3	5.53	5.53	5.77	5.90
	Income 4	7.06	7.22	7.50	8.10

Table 9: *Enrolment Gaps with Respect to the Top Income Quartile for Different Ability Quartiles, Economy 2000*

	Ability Quart. 1	Ability Quart. 2	Ability Quart. 3	Ability Quart. 4
	Panel A – All Parents			
income 4-1	0.78	0.81	0.61	0.36
income 4-2	0.67	0.45	0.09	0.03
income 4-3	0.59	0.33	0.01	0
	Panel B – High School Educated Parents			
income 4-1	0.72	0.72	0.60	0.36
income 4-2	0.62	0.36	0.09	0.03
income 4-3	0.54	0.27	0.01	-0.002
	Panel C – College Educated Parents			
income 4-1	–	–	–	–
income 4-2	–	–	–	–
income 4-3	0.12	0.007	0	0

Notes: Enrolment gaps are computed for different ability quartiles, without controlling for parental education (panel A), only for children with high-school graduates parents (panel B) and for children with college graduated parents (panel C). An entry for 'income 4-1' of 0.29 indicates that the enrolment rate in the lowest income quartile is about 30 percentage points below the enrolment rate of the highest income quartile. A missing entry (–) indicates that there are no children with parents in this category.

Table 10: *Economy 2000: Average savings of high school graduates (model period j = 31), controlling for their wealth and income quartile, and the ability quartile of their children.*

		Ability 1	Ability 2	Ability 3	Ability 4
Wealth 1	Income 1	1.78	1.71	1.55	1.34
	Income 2	2.16	2.02	1.75	1.44
	Income 3	2.39	2.11	1.79	1.67
	Income 4	-	-	-	-
Wealth 2	Income 1	3.61	3.16	2.78	2.83
	Income 2	4.24	3.75	3.31	3.31
	Income 3	4.17	3.68	3.35	3.57
	Income 4	-	-	-	-
Wealth 3	Income 1	5.48	5.14	4.82	4.82
	Income 2	5.35	4.96	4.61	4.64
	Income 3	5.82	5.44	5.30	5.72
	Income 4	-	-	-	-
Wealth 4	Income 1	6.68	6.27	5.90	5.90
	Income 2	7.58	7.43	7.44	7.82
	Income 3	7.95	7.75	7.79	8.26
	Income 4	10.48	10.47	10.59	10.95

Table 11: *Economy 2000: Average savings of college graduates (model period j = 31), controlling for their wealth and income quartile, and the ability quartile of their children.*

		Ability 1	Ability 2	Ability 3	Ability 4
Wealth 1	Income 1	-	-	-	-
	Income 2	-	-	-	-
	Income 3	1.64	1.61	1.61	1.61
	Income 4	1.42	1.80	1.93	1.99
Wealth 2	Income 1	-	-	-	-
	Income 2	-	-	-	-
	Income 3	2.67	3.09	3.12	3.17
	Income 4	2.81	3.24	3.42	3.64
Wealth 3	Income 1	-	-	-	-
	Income 2	-	-	-	-
	Income 3	4.27	4.83	4.87	5.31
	Income 4	4.40	4.97	5.03	5.53
Wealth 4	Income 1	-	-	-	-
	Income 2	-	-	-	-
	Income 3	5.20	5.85	5.90	6.48
	Income 4	7.85	8.52	8.66	9.14

Table 12: *Average Savings and Transfers of High School and College Graduates (in 1983 US-Dollar)*

		no controls	controls
Savings	High School	14200	92334
	College	92200	81953
Transfers	High School	1330	7725
	College	11900	11100

Notes: All values are obtained through an OLS regression of savings or transfers on a set set of dummy variables. The first column only controls for the education level, while the second column also includes dummies for the wealth and income level. The results in the second column are predicted values for a household in the third income percentile the fourth wealth percentile. Regressions are weighted using the SCF frequency weights. All results are statistically significant at the 5% level