Education Policy and Intergenerational Transfers in Equilibrium

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We examine the equilibrium effects of college financial aid policies building an overlapping-generations life cycle model with education, labor supply, and saving decisions. Cognitive and noncognitive skills of children depend on parental education and skills and affect education and labor market outcomes. Education is funded by parental transfers that supplement grants, loans, and student labor supply. Crowding out of parental transfers by government programs is sizable and cannot be ignored. The current system of federal aid improves long-run welfare by 6 percent. More generous ability-tested grants would increase welfare and dominate both an expansion of student loans and a labor tax cut.

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I. Introduction

Investment in human capital is a key source of aggregate productivity growth and a powerful vehicle for social mobility. However, imperfections in insurance and credit markets can distort skill investment choices and lead to less than socially optimal educational attainment. Motivated by these considerations, governments promote the acquisition of education through a variety of interventions. Financial aid for college students is a pillar of education policy in many countries. For example, in 2012 the US federal government spent 150 billion dollars on loans and grants for college students (College Board 2012). Given their magnitude and scope, it is important to quantify the effects of policies intended to advance college attainment and understand the way they interact with private financing of education.

In this paper we build a life cycle, heterogeneous agent model with incomplete insurance and credit markets of the type popularized by Ríos-Rull (1995) and Huggett (1996), featuring intergenerational links in the tradition of Laitner (1992) and set in an overlapping-generations context. Throughout their life cycles, parents make savings and labor supply decisions, and when their children are old enough, they make financial transfers to them. These transfers depend on the policy environment (such as the availability of financial aid) and are motivated by both altruism and a paternalistic preference for children's education. Cognitive and noncognitive skills transmitted across generations determine the nonpecuniary cost of education for students and productivity once entering the labor market. Government grants and loans, private loans, as well as labor supply during college complement parental resources as means of funding the financial cost of college education. Workers of different gender and education are imperfect substitutes in production. The government redistributes through a progressive tax system.

With this rich structure in hand, we study the impact of financial aid policies on college attainment, welfare, and the aggregate economy. Central to our analysis are the roles of liquidity constraints and uninsurable income risk, policy-induced crowding out of private sources of funding, heterogeneity and selection, and general equilibrium feedbacks.

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Since Becker (1964), the potential importance of liquidity constraints on education attainment is well understood. The extent to which credit market imperfections can distort college attendance depends on the capacity and willingness of parents to fund education for their children, the availability of government-sponsored grants and loans, and the earnings potential of students.[1] Gale and Scholz (1994) show that inter vivos transfers for education are sizable.[2] However, studies using data from the 1980s and 1990s concluded that family income played a small role in college attendance decisions, after controlling for child ability and several family background characteristics (Cameron and Heckman 1998; Keane and Wolpin 2001; Carneiro and Heckman 2002; Cameron and Taber 2004). More recently, though, Belley and Lochner (2007) found that parental financial resources matter significantly for college attendance in the 2000s. In turn, Heckman and Mosso (2014) argue that much of the family income effect estimated in the 2000s results from low-ability children, while high-ability children were already in school.[3]

Earnings risk is pervasive and only partially insurable (Blundell, Pistaferri, and Preston 2008; Low, Meghir, and Pistaferri 2010; Heathcote, Storesletten, and Violante 2014). It can affect individual decisions as well as the impact of policy, including the relative benefit of grants versus loans.[4] Thus, we model earnings as a gender-specific stochastic Roy model with a separate process for each education group and dependent on ability. We explicitly account for alternative channels of consumption insurance, including spousal labor supply (as in Blundell, Pistaferri, and Saporta-Eksten [2016b]) and intrafamily transfers.

In the model, we allow for heterogeneity in both the returns to education and the psychic costs of schooling, which depend on both cognitive and noncognitive ability.[5] Modeling psychic costs is necessary because

[1] Garriga and Keightley (2015) show that omitting the labor supply margin of college students may lead to large overestimates in the effects of tuition subsidies.

[2] Winter (2014) also argues that ignoring parental transfers may lead to wrong inference about the extent of credit constraints. Keane and Wolpin (2001) and Johnson (2013) estimate parental inter vivos transfers as a function of observable characteristics from the National Longitudinal Survey of Youth 1979 cohort (NLSY79). Brown, Scholz, and Seshadri (2012) show that while parental contributions are assumed and expected in financial aid packages, they are not legally enforceable or universally given, implying substantial heterogeneity in access to resources for students with observationally similar families.

[3] Carneiro, Heckman, and Vytlacil (2011) show that returns to college are in fact negative for low-ability children.

[4] See, e.g., Johnson (2013). As originally emphasized by Levhari and Weiss (1974), college education is a multiperiod investment requiring an ex ante commitment of resources and time. Uncertainty in its return is a key determinant of education decisions. Hence, students may be unwilling to finance college using loans when risk about their future earnings and ability to repay is high.

[5] The first studies linking human capital investment to life cycle earnings (Mincer 1958; Becker 1964; Ben-Porath 1967) sidestepped the important issue of self-selection into education, as described in the seminal contributions of Rosen (1977) and Willis and Rosen (1979).

pecuniary returns can account for only part of the observed college attendance patterns by ability (see Cunha, Heckman, and Navarro [2005] and Heckman, Lochner, and Todd [2006a]). From a policy perspective, accounting for such heterogeneity allows a meaningful examination of the importance of targeted interventions. The way cognitive and noncognitive skills are transmitted across generations as well as their effects on education choices and returns are estimated from data. In particular, because parental education affects child skills in the model, thus making them endogenous, expanding schooling for the current generation reduces the cost of human capital accumulation for future generations, an original insight of T. W. Schultz.[6]

To complete our understanding of how government policy can affect educational attainment and wages, we follow Heckman, Lochner, and Taber (1998b, 1998c), Lee (2005), and Lee and Wolpin (2006), among others, and set the model in a general equilibrium context, which allows wages to adapt to changes in the supply and composition of educated workers.[7] In our model, the aggregate production function depends on inputs from three types of education and allows for imperfect substitutability between males and females of the same skill.

Finally, to shed light on the welfare effects of education policy, we build on Benabou (2002) and develop a decomposition of welfare gains into aggregate productivity improvements, lower inequality in initial conditions, and reduced consumption uncertainty.

Our data are drawn from various US sources, including the Current Population Survey (CPS), the Panel Study of Income Dynamics, NLSY79 and NLSY97, the National Center for Education Statistics (NCES), the Survey of Consumer Finances (SCF), and the National Accounts. The model is estimated in stages. We first estimate the wage processes for each education group and gender as well as the intergenerational transmission of ability and the aggregate production function. Then, having set few parameters based on the literature, we use the method of moments to estimate the rest of the model's parameters. The US federal system of grants and loans is represented in detail, allowing for the existing amount of means testing, to ensure that we capture the main sources of public funding for education and the way they are targeted in practice.

We establish that the model fits the data along a number of crucial dimensions that are not targeted in estimation. For example, cross-sectional life cycle profiles of the mean and dispersion of hours worked, earnings,

[6] The dependence of child cognitive and noncognitive skills on parental education in part reflects how investments in child development vary with parental education (Cunha and Heckman 2007; Cunha, Heckman, and Schennach 2010). This provides an important channel for the intergenerational impact of education policy.

[7] For a similar approach, see also the work of Bohacek and Kapicka (2012), Johnson and Keane (2013), Krueger and Ludwig (2016), and Garriga and Keightley (2015).

consumption, and wealth are consistent with their empirical counterparts. We are careful to match numerous statistics about student borrowing, including their average cumulative loans upon graduation.[8] The intergenerational income rank mobility implied by our model is within the range estimated by Chetty et al. (2014), and correlation of income between parents and children is close to the value documented by Solon (1999) for the United States. Our modeling choices for federal financial aid imply marginal effects of parental wealth on college attainment (controlling for child's ability) that are similar to those estimated by Belley and Lochner (2007) from the NLSY97. The role of paternalism is key in explaining these facts. Moreover, when we use the model to simulate an artificial randomized experiment in which a (treated) group of high school graduates receives an additional $1,000 in yearly tuition grants and another (control) group does not, the simulated treatment effect on college attainment is consistent with the outcomes of quasi-randomized policy shifts surveyed by Deming and Dynarski (1995) and Kane (2003).

We conduct a number of different policy experiments, in which we change the size and nature (general, need based, merit based) of the federal grant program and government-sponsored loan limits. We find that the crowding out of the private (parental) source of funds is a very important feature that attenuates the effects of policy: every additional dollar of government grants crowds out 25–50 cents of parental inter vivos transfers on average, and a $1,000 reduction in tuition fees lowers the annual earnings of college students by roughly $100 on average. The amount of crowding out varies across the wealth distribution, with transfers from poorer parents being more sensitive to policy changes. Overall, however, the current level of federal aid (grants and loans) is welfare improving and accounts for more than 4 percent of GDP, with the grants and loans being of roughly equal importance. Our estimated model also implies nontrivial welfare and efficiency gains from further expansions of grant programs. An additional $1,000 of grants per year for every student (which increases grant spending by roughly 50 percent) leads to a long-run increase in GDP of close to 1 percent. While some of this gain derives from increased college attainment, a substantial part also arises from stronger sorting into college on the basis of ability, which is efficient in the model. An ability-tested grant expansion is significantly more effective than a general expansion. One source of this result is the complementarity between parental education and ability in the production of children's skills. Finally, consistent with the literature, the general equilibrium responses of wages—together with crowding out—imply that the aggregate long-run effects are less than half the immediate response.

[8] Lochner and Monje-Naranjo (2011) stress that models may imply too little borrowing relative to data.

The remainder of the paper is organized as follows. Section II outlines the model and defines equilibrium. Section III describes estimation. Section IV explores the empirical implications of the model by assessing its behavior along several key dimensions not explicitly targeted in the parameterization. Section V presents all the policy experiments and offers a general discussion of the main findings. Section VI concludes the paper. An online appendix contains additional details on the parameterization and the results of the policy experiments as well as a sensitivity analysis.

II. Model

A. *Overview*

Men and women in the model start making choices at age 16. At that point, cognitive and noncognitive skills are drawn from a distribution that depends on parental education and skills. Moreover, parents make financial transfers to their children with which they start them out in life. These inter vivos transfers are in part unconditional (driven by altruism) and in part conditional on children attending college (driven by paternalism). The inter vivos transfers and the ability transmission drive intergenerational mobility. Given these transmitted endowments of financial resources and abilities, children make their sequential education choices, which can be one of three: less than high school, high school, or college. During college, students can finance education by borrowing from private markets, through government grants and loans, and also by working part-time. Once education is completed, individuals marry, drawing a spouse from a distribution that reflects the educational sorting in the data. Over the life cycle, they make consumption/savings and labor supply decisions, and they exogenously have two children of the same gender. After their children have become independent decision makers, they continue with the standard life cycle decisions and eventually retire off their savings and a government-provided pension, living to a maximum age of 100.

There is a set of overlapping generations at any point in time. Workers of different skills, genders, and education combine to produce a consumption good, based on a production function where workers of different genders and education are imperfect substitutes for each other; skills enhance the efficiency units of labor supplied. We assume a closed economy in which capital is endogenously determined by the savings of households. Interest rate and wages clear the capital and labor markets. The government uses taxation to fund educational programs (grants and loans), pensions, and other (residual) expenditures.

We begin by describing the model's demographic structure, preferences, production technology, financial markets, and government policies.

Next, we outline the life cycle of agents and define a competitive equilibrium. We abstract from aggregate shocks and thus describe the economy in steady state. For this reason, to lighten notation, we omit time subscripts whenever possible. When discussing the choice of parameter values requires no detour, we do it as we present the model. This subset of parameter values is summarized in the tables in the appendix. The rest of the parameterization is outlined in Section III.

B. Preliminaries

Time is discrete, indexed by t, and continues forever. There is no aggregate uncertainty. A period in the model corresponds to 2 years. The economy is populated by a continuum of individuals, equally many males and females. Gender is indexed by $g \in \{m, f\}$ and age by $j \in \{0, 1, \ldots, J\}$. At each date, a new cohort of measure one of each gender enters the economy. The first period of life in the model ($j = 0$) corresponds to age 16 and the last one ($j = J$) to age 100. Individuals survive from age j to $j + 1$ with probability ζ_j (strictly less than 1 only after retirement), whose values are taken from the US Life Tables for the year 2000. Since cohort size and survival probabilities are time invariant, the model's age distribution is stationary.

The life cycle of individuals comprises four stages: education from age $j = 0$ to a maximum of age j^{CL}, marital matching at age $j^{CL} + 1$, work until age $j^{RET} - 1$, and retirement from age j^{RET} to J. In the first stage, the decision unit is the individual. In the last two, the decision unit is the household, that is, a husband and wife pair.

1. Preferences

The consumption and leisure of an individual with gender $g \in \{m, f\}$ at age j are denoted by c_j^g and ℓ_j^g, respectively. We will minimize/suppress subscripts wherever possible in the following discussion to improve readability. Individuals have gender- and age-specific preferences over consumption c and leisure ℓ:

$$u_{gj}(c, \ell) = \frac{c^{1-\gamma}}{1-\gamma} + \vartheta_j^g \frac{\ell^{1-\nu_j^g}}{1-\nu_j^g}. \tag{1}$$

Some of the preference parameters above are preset on the basis of existing literature: the coefficient of relative risk aversion γ is set to 1.5 (see Attanasio and Weber 1995). For males, ν^m and ϑ^m do not depend on age; ν^m is set so that the (average) Frisch elasticity of labor supply is 1/3, while ϑ^m is estimated.[9] For women, each of these parameters takes two values:

[9] See Meghir and Phillips (2009) for estimates of Frisch elasticities for men.

one for when they have no children in the household—the same values they take for men—and one for when they do (ages 30–45). The Frisch elasticity for women with children is 2/3, following Blundell et al. (2016a). As for males, ϑ_j^f are estimated and take two values depending on whether women have children or not (which here just depends on age).[10] The discount factor β, common across individuals, is a key determinant of wealth accumulation. To inform the estimation of this parameter, we therefore target an aggregate capital-output ratio of 3.5 annually, as in the US economy, and obtain an annualized value of $\beta = 0.951$.

We assume full ex ante commitment within the marriage. Married couples have household preferences

$$u_j(c^m, c^f, \ell^m, \ell^f) = u_{mj}(c^m, \ell^m) + u_{fj}(c^f, \ell^f) + v^m + v^f, \tag{2}$$

where v^g denotes transfers of utility between spouses (with $v^m + v^f = 0$) that allow the initial commitment to be fulfilled ex post.[11]

We follow Voena (2015) by modeling economies of scale in consumption as dependent on the sharing of resources. That is, total expenditure to consume c^m and c^f is $c = [(c^m)^{\tilde{\rho}} + (c^f)^{\tilde{\rho}}]^{1/\tilde{\rho}}$. The optimal allocation of consumption within the marriage requires $c^m = c^f$. Hence, we have $c = 2^{1/\tilde{\rho}} c^g$, where $\tilde{\rho} = 1.4$, as estimated by Voena (2015), implies sizable economies of scale for couples.

2. Production

All final goods are produced by a representative firm using aggregate physical capital K and an aggregate human capital input $\mathcal{H}$, according to the production technology $Y = F(K, \mathcal{H})$, where F is Cobb-Douglas. We exogenously set the capital share of output α to 0.33 and the annual capital depreciation rate δ to 0.06.

We follow Katz and Murphy (1992) and Heckman, Lochner, and Taber (1998a) in modeling aggregate labor input $\mathcal{H}$ as a constant elasticity of substitution aggregator of six types of labor inputs, $H^{e,g}$, indexed by gender g and education attainment $e \in \{LH, HS, CL\}$, where LH denotes those who did not complete high school, HS denotes high school graduates, and CL denotes college graduates:

$$\mathcal{H} = [s^{LH}(H^{LH})^{\rho} + s^{HS}(H^{HS})^{\rho} + s^{CL}(H^{CL})^{\rho}]^{1/\rho}, \tag{3}$$

[10] The key moments that identify the weight on nonmarket time ϑ_j^f and ϑ_m are the average hours worked. For men and childless women, this is 35 percent of their time endowment. When children are present, women work 40 percent less than men (as in the CPS 2000 data).

[11] This specification is consistent with the transferable utility model described by Weiss (1997, 89–90).

where

$$H^e = \left[s^{f,e}(H^{f,e})^\chi + s^{m,e}(H^{m,e})^\chi\right]^{1/\chi}, \tag{4}$$

where $e \in \{LH, HS, CL\}$. Both ρ and χ are in $(-\infty, 1]$. Each labor market is assumed to be competitive. The estimation of the elasticities of substitution and the CES weight parameters $s^{g,e}$, on the basis of data from the CPS for 1968–2001, is done separately and before the main model estimation. It takes into account that individuals have different skills that affect the number of efficiency units of labor that they supply. This is discussed in Section III.

3. Financial Markets

Markets are incomplete. Agents trade claims to physical capital and risk-free bonds but cannot buy state-contingent insurance against individual risk. All financial contracts are transacted by competitive intermediaries (banks). Claims to capital and bond holdings pay the same return in equilibrium because of no arbitrage. Households with positive savings receive from banks an equilibrium interest rate that equals r. Banks lend the funds to other households with borrowing needs at the rate $r^- = r + \iota$, where the wedge $\iota > 0$ is the cost of overseeing the loan per unit of consumption intermediated. The wedge ι is an important determinant of the proportion of households who have negative net worth. In the 2001 SCF data, this proportion is 6.8 percent, which we target in estimation. Our estimate of the unsecured borrowing wedge is $\iota = 0.064$ annually.

Individuals face debt limits that vary over the life cycle. High school students, young (i.e., before marriage) workers, and retired households cannot borrow. Credit access for the college students is explained in detail below. Working-age married households are subject to borrowing constraints $\underline{a}^e$. The value of $\underline{a}^e$ is set to $-\$85{,}000$ if the most educated spouse is a college graduate, $-\$25{,}000$ if the most educated spouse is a high school graduate, and $-\$15{,}000$ if both spouses have attained less than high school. These exogenously specified parameters values are informed by self-reported limits on unsecured credit by family type from the SCF.[12] All retired households can buy annuities at actuarially fair rates, which allows us to abstract from bequests.[13]

[12] The lifetime natural borrowing limit (households cannot retire with debt) may be more restrictive for some households, particularly those approaching retirement.

[13] As explained, one reason financial markets are incomplete is that there are no state-contingent insurance markets for (1) individual labor income risk. As will be clear from the description of the rest of the model, there are also missing markets to insure (2) the risk of being born with disadvantaged initial conditions (e.g., poor, uneducated, or low-ability parents), (3) the shocks affecting the psychic cost of education, and (4) adverse outcomes at the marital matching stage.

4. Government

The government levies flat taxes $\tau_w = 0.27$, $\tau_k = 0.40$, and $\tau_c = 0.05$ on labor income, asset income, and consumption, respectively (see Domeij and Heathcote 2004; McDaniel 2014).[14] The government refunds a lump sum amount of tax revenue ψ to each individual. The value of ψ largely determines the progressivity of the tax system (how average tax rates vary with income). We measure progressivity by the ratio of the variance of disposable income to the variance of pregovernment income, which is about 0.61 in national data (see Heathcote, Perri, and Violante 2010). This progressivity statistic is important for identification of ψ, and thus we include it as a targeted moment in estimation. The government also runs a public pension system that pays an education-specific benefit p^e to retirees. The pension replacement rate is exogenously specified as 33 percent of average earnings within each respective education group (Mitchell and Phillips 2006). Once the education and pension systems have been financed, excess tax revenues are spent on nonvalued government consumption G.

C. Life Cycle

The life cycle of an individual consists of four phases—education, marital matching, work, and retirement—which we now describe.

1. Education

The education stage lasts three periods and includes two decisions. At the onset of the first period of adult life ($j = 0$), individuals choose whether to finish high school or enter the labor market. In the second period, those who completed high school decide whether to attend college, which lasts for two periods if chosen. Since there is no uncertainty during college, in our model college students do not drop out.[15]

As analyzed by Cunha et al. (2005) and Heckman et al. (2006a), psychic costs—reflecting preparedness or taste for education—are an important component of schooling decisions. In our model, an individual's utility

[14] The tax τ_k is levied only on positive capital income. We use τ_k throughout with the convention that if $a < 0$, then $\tau_k = 0$.

[15] Individuals can therefore enter the labor force at age $j = 0$ with less than high school attainment, at age $j = 1$ as high school graduates, or at age $j = 3$ as college graduates. To avoid further complexity, we abstract from modeling the college dropout decision. The vast majority of dropouts occur in the freshman year, and dropout rates are far higher for part-time than for full-time students. Thus, for the most part, very little commitment has been made among the vast majority of those who choose not to complete college, and the absence of outlays of time and money by dropouts in our model of high school graduates is likely to be of little substance. When relating to the data, we count only those who complete college as having attended.

cost κ_g^e of attaining education level e depends on gender, standardized cognitive skills θ_{cog}, standardized noncognitive skills θ_{non} (with the pair summarized by the vector $\boldsymbol{\theta}$), and an idiosyncratic preference shock κ_ϵ. This shock is common to high school and college (but with a different loading) and is drawn from a standard normal distribution. Specifically, we assume the linear relationship

$$\kappa_g^e(\boldsymbol{\theta}, \kappa_\epsilon) = \varsigma_0^e + \varsigma_1^e \mathbf{1}_{\{g=f\}} + \varsigma_2^e \frac{\log(\theta_{non})}{\sigma_{non}} + \varsigma_3^e \frac{\log(\theta_{cog})}{\sigma_{cog}} + \varsigma_4^e \kappa_\epsilon, \tag{5}$$

where $(\sigma_{non}, \sigma_{cog})$ are the standard deviations of the logs of the two components of ability. The education-specific coefficients $(\varsigma_1^e, \varsigma_2^e, \varsigma_3^e, \varsigma_4^e)$ are included in our main estimation and discussed in Section III.

These education decisions involve comparison of lifetime values under the different scenarios. In what follows, let the value of continuing in school for an individual with gender g and age j be V_{gj}^* and the value of entering the workforce with education e be V_{gj}^e.

When individuals start out making choices, they know their own cognitive and noncognitive ability $\boldsymbol{\theta}$ and the random component of psychic cost κ_ϵ of continuing education. They also know the amount of transfers parents will make. Denote the unconditional transfer by $\hat{a}_0$ and the component of the transfer conditional on attending college by $\hat{a}^{CL}$. Finally, they know their eligibility status for college financial aid in the form of grants $\mathfrak{g}$ and loans b, denoted by the index $q \in \{1, 2, 3\}$, which as we explain below depends on parental income and wealth. Let this starting set of initial conditions be $\boldsymbol{x}_0^* = (\boldsymbol{\theta}, \kappa_\epsilon, \hat{a}, \hat{a}^{CL}, q)$. It is also useful to summarize the set of initial conditions for an individual who decides to stop schooling and enter the labor force as $\boldsymbol{x}_0 = (\boldsymbol{\theta}, a_0 = \hat{a}, z_0)$, where a_0 is the initial level of wealth and z_0 is the initial productivity draw (which is unknown at the time of the decision).

At the time of this first decision, the value of an individual can therefore be written as

$$\mathcal{V}_{g0}(\boldsymbol{x}_0^*) = \max\left\{ V_{g0}^*(\boldsymbol{x}_0^*) - \kappa_g^{HS}(\boldsymbol{\theta}, \kappa_\epsilon), \mathbb{E}_0\left[V_{g0}^{LH}(\boldsymbol{x}_0)\right]\right\}, \tag{6}$$

where $\mathbb{E}_0$ is the expectation operator over the initial productivity draw.[16] In all our policy counterfactuals of Section V, welfare calculations are based on this initial value function $\mathcal{V}_{g0}$.

Individuals who choose to enter the labor force at age $j = 0$ with $e = LH$ (or at age $j = 1$ with $e = HS$) solve the follow problem:

[16] Note that the state vector for those who continue into high school is the same as the initial one because no new information is revealed to them at that point, which explains the use of $\boldsymbol{x}_0^*$ on the right-hand side of eq. (6).

$$
\begin{aligned}
V_{gj}^{e}(\boldsymbol{x}_j) &= \max_{c_j,\ell_j,a_{j+1}} u_g(c_j,\ell_j) + \beta\mathbb{E}_j\left[V_{g,j+1}^{e}(\boldsymbol{x}_{j+1})\right] \text{ such that} \\
(1+\tau_c)c_j + a_{j+1} &= (1-\tau_w)w^{g,e}\varepsilon_j^{g,e}(\boldsymbol{\theta}, z_j)(1-\ell_j) \\
&\quad + \psi + [1 + r(1-\tau_k)]a_j, \\
a_{j+1} &\geq 0,\ c_j \geq 0,\ \ell_j \in [0,1], \\
z_{j+1} &\sim \Gamma_z^{g,e}(z_{j+1} \mid z_j),
\end{aligned}
\tag{7}
$$

where $\mathbb{E}_j$ is the expectation operator conditional on the information set at age j, $\boldsymbol{x}_j = (\boldsymbol{\theta}, a_j, z_j)$, and $w^{g,e}$ is the gender- and education-specific price for a unit of human capital. The gender-, age-, and education-specific function $\varepsilon_j^{g,e}$ relates ability $\boldsymbol{\theta}$ and idiosyncratic productivity shock z_j to productive efficiency per unit of labor supplied. The exact dependence of $\varepsilon_j^{g,e}$ on $\boldsymbol{\theta}$ and z_j and the Markov process of the productivity shock Γ_{gz}^{e} are described in detail in Section III.

The value of completing high school as seen from age $j = 0$ is defined by

$$
\begin{aligned}
V_{g0}^{*}(\boldsymbol{x}_0^{*}) &= \max_{c_0,a_1} u_g(c_0, 1-\bar{t}) \\
&\quad + \beta \max\left\{V_{g1}^{*}(\boldsymbol{x}_1^{*}) - \kappa_g^{CL}(\boldsymbol{\theta}, \kappa_\epsilon), \mathbb{E}_0\left[V_{g1}^{HS}(\boldsymbol{x}_1)\right]\right\} \text{ such that} \\
a_1 &= [1 + r(1-\tau_k)]\hat{a}_0 - c_0(1+\tau_c) + \psi, \\
a_1 &\geq 0,\ c_0 \geq 0.
\end{aligned}
\tag{8}
$$

High school students can neither borrow nor work. They study for a fraction $\bar{t} = 0.25$ of their time endowment and consume the rest as leisure. If they decide to continue to college, their state vector gets updated to $\boldsymbol{x}_1^{*} = (\boldsymbol{\theta}, a_1 + \hat{a}^{CL}, q)$, since they receive the conditional transfer from their parents.

College lasts for two (2-year, $j = 1$ and $j = 2$) periods. Thus, the values of being in college in the initial and final periods are

$$
V_{g1}^{*}(\boldsymbol{x}_1^{*}) = \max_{c_1,\ell_1,a_2,b_2} u_g(c_1,\ell_1) + \beta V_{g2}^{*}(\boldsymbol{x}_2^{*}), \tag{9}
$$

$$
V_{g2}^{*}(\boldsymbol{x}_2^{*}) = \max_{c_2,\ell_2,a_3,b_3} u_g(c_2,\ell_2) + \beta\mathbb{E}_3\left[V_{g3}^{CL}(\boldsymbol{x}_3)\right], \tag{10}
$$

where $\boldsymbol{x}_2^{*} = (\boldsymbol{\theta}, a_2, b_2, q)$ and the expectation operator in the second value function captures the uncertainty with respect to the initial productivity draw of college graduates.[17] These two maximization problems are subject

[17] The state vector $\boldsymbol{x}_3$ includes ability, assets, and the initial draw of the labor productivity shock z.

to a number of constraints: first, the nonnegativity of consumption $c \geq 0$; and second, the time allocation constraint $\ell_j \in [0, 1 - \bar{t}]$: labor supply in college is flexible, but the time endowment available for work is reduced by $\bar{t}$ units to reflect the time required for learning. Working students supply high school equivalent labor.[18]

We now turn to college students' budget constraints, which also illustrate how government programs affect schooling choices. All students have access to unsubsidized student loans up to a value $\underline{b}$. Unsubsidized loans cumulate interest at rate r^u both during and after college. Students with financial need, measured by their parents' resources $(q = 1)$, have access to subsidized loans up to a limit $\underline{b}^s$. Interest on subsidized loans is forgiven during college. Those with wealthy parents $(q = 3)$ have access to private loans at the rate r^p. Because $r^p < r^u$, and because the credit limit on private loans $\underline{a}^p$ allows them to fully fund college through private credit, students with $q = 3$ who choose to borrow always select this option.[19] Federal grants $\mathfrak{g}$ are awarded by the government through a formula that makes them a function of both parental wealth and student abilities. Hence, we allow grants to be both need based and merit based. To simplify notation, we refer to $\phi(q, \boldsymbol{\theta})$ as tuition fees ϕ net of grants $\mathfrak{g}(q, \boldsymbol{\theta})$. Next, we state the college students' budget constraints.

A student with wealthy parents $(q = 3)$ has the option to borrow privately and faces the following budget constraint:

$$
\begin{aligned}
&(1 + \tau_c)c_j + a_{j+1} - (1 - \tau_w)w^{g,HS}\varepsilon_j^{g,HS}\big(\boldsymbol{\theta}, z_j = 0\big)\big(1 - \bar{t} - \ell_j\big) \\
&\qquad + \phi(q, \boldsymbol{\theta}) - \psi \\
&= \begin{cases} [1 + r(1 - \tau_k)]a_j & \text{if } a_j \geq 0, \\ (1 + r^p)a_j & \text{otherwise,} \end{cases}
\end{aligned}
\tag{11}
$$

[18] For simplicity, their labor productivity $\varepsilon_j^{g,HS}$ in the budget constraint below is allowed to depend only on gender, age j, and ability $\boldsymbol{\theta}$. Implicitly, we are assuming that every college student has idiosyncratic productivity value equal to the population mean $(z = 0)$. Moreover, in our model we do not allow for potential disruptions to schooling effort associated with working while in college. See Garriga and Keightley (2015) for a model where time devoted to work competes with time needed to cumulate credits in college. Our model generates average hours worked by students approximately equal to 15 hours per week. In comparison, Garriga and Keightley (2015) report 20 hours per week worked by students on average. In addition to this, our model also fits the extensive margin reasonably well. For example, in the NCES Baccalaureate and Beyond data for graduating seniors 2007–8, 19 percent of students reported not working, and in our model 14 percent of students choose not to work.

[19] Implicitly, interest rates on private education loans depend on credit scores (see Ionescu and Simpson 2016). As a result, poor families with low credit scores face high borrowing rates on private education loans. Implicitly, we assume that these rates are so high that poor families choose not to use the private market to finance their children's education.

where $a_{j+1} \geq -\underline{a}^p$. A student who qualifies for only unsubsidized government loans ($q = 2$) faces the budget constraint

$$\begin{aligned}(1+\tau_c)c_j + a_{j+1} + b_{j+1} - (1-\tau_w)w^{g,HS}\varepsilon_j^{g,HS}\big(\boldsymbol{\theta}, z_j = 0\big)\big(1-\bar{t}-\ell_j\big) \\ + \phi(q,\boldsymbol{\theta}) - \psi \\ = \begin{cases}[1+r(1-\tau_k)]a_j & \text{if } a_j \geq 0,\ \ b_j = 0, \\ (1+r^u)b_j & \text{if } a_j = 0,\ \ b_j < 0,\end{cases}\end{aligned} \tag{12}$$

where $a_{j+1} \geq 0$ and $b_{j+1} \geq -\underline{b}$. A wealth-poor student who qualifies for a subsidized government loan ($q = 1$) faces the budget constraint

$$\begin{aligned}(1+\tau_c)c_j + a_{j+1} + b_{j+1} - (1-\tau_w)w^{g,HS}\varepsilon_j^{g,HS}\big(\boldsymbol{\theta}, z_j = 0\big)\big(1-\bar{t}-\ell_j\big) \\ + \phi(q,\boldsymbol{\theta}) - \psi \\ = \begin{cases}[1+r(1-\tau_k)]a_j & \text{if } a_j \geq 0,\ \ b_j = 0, \\ b_j & \text{if } a_j = 0,\ \ 0 > b_j \geq -\underline{b}^s, \\ -\underline{b}^s + (1+r^u)\big(b_j + \underline{b}^s\big) & \text{if } a_j = 0,\ \ b_j < -\underline{b}^s,\end{cases}\end{aligned} \tag{13}$$

where $a_{j+1} \geq 0$ and $b_{j+1} \geq -\underline{b}$.

We parameterize tuition costs, grants, and student loans using data published by the NCES for the year 2000 (source: Student Financing of Undergraduate Education: 1999–2000, Statistical Analysis Report). In online appendix A, we provide a detailed description of the federal system of financial aid to college students (as in the year 2000) that we aim to reproduce in estimation.

Some of these parameters can be set externally because they have an exact counterpart in the data (see table A1). We define the cost of college as tuition fees plus the cost of books and other academic material net of institutional and private grants, and we compute an average across all full-time, full-year dependent students enrolled in private not-for-profit and public 4-year colleges in the year 2000. We obtain an average annual cost ϕ of \$6,700. Federal and state grants $\mathfrak{g}$ are means tested, with children of low-wealth ($q = 1$), middle-wealth ($q = 2$), and high-wealth ($q = 3$) parents receiving \$2,820, \$668, and \$143 per year, respectively. Thus, net annual tuition ϕ $(q, \boldsymbol{\theta})$ is \$6,700 minus the applicable federal grant, depending on q.

Cumulative borrowing limits for federal loans to (dependent) students were \$23,000 in year 2000, of which a maximum \$17,250 could be subsidized if the student qualified. We use these values to set $\underline{b}$ and $\underline{b}^s$, and we specify $\underline{a}^p$ so that cumulative private and federal borrowing limits are equal. Moreover, in 2000 the interest rate on federal student loans was prime (r^- in our model) plus 2.6 percent, in addition to initiation fees that were on average 0.5 percent. Thus, we set $r^u = r^- + \iota^u$, where $\iota^u = 0.031$ annually.

The rest of the parameters are internally estimated. In 2000, to qualify for a subsidized loan (status $q = 1$), a child's family must pass two tests. The first is a potential income test, which stipulates that the higher-earning parent would earn less than a full-time equivalent of $55,000.[20] The second test is a parental wealth test based on a threshold that is included as a parameter in our main estimation. A higher-wealth threshold, also internally estimated, determines eligibility for unsubsidized loans (status $q = 2$). Students of type $q = 3$ with parental wealth above this second threshold borrow privately at the rate $r^p = r^- + \iota^p$, where ι^p is to be estimated as well. We include three moments in estimation that are especially informative about these three parameters: (1) federal student loans were taken out by 62.1 percent of graduating seniors, (2) subsidized federal loans were taken out by 41.9 percent of such students, and (3) 13.4 percent of students did not use any form of government aid. We estimate the two eligibility thresholds to be approximately $124,000 and $168,000 and the private student loan annual interest premium to be 0.029.

To simplify the computation, we assume that at the end of college all student debt (private and federal loans) is refinanced into a single private bond that carries the interest rate r^-. Define $\tilde{a}_3$ as the student net asset position based on assets a_3 (possibly negative for those borrowing from the private sector), federal student loans b_3, and the qualification indicator q. For those students who graduate with debt, $\tilde{a}_3$ is computed as the present value of all future payments that must be made on student loans, depending on the amount borrowed and applicable interest rates, discounted at rate r^-. When making this calculation, we assume that fixed payments would have been made for 10 periods following graduation. This approach provides a close approximation to a setting where fixed installments are required for a given number of periods, but households can use unsecured debt to make these payments if necessary.[21] Online appendix A illustrates this conversion scheme in more detail. Because of this simplification, at the end of period $j = 3$, college graduates enter the marital matching stage with $\boldsymbol{x}_3 = (\boldsymbol{\theta}, \tilde{a}_3, z_3)$.

[20] The NCES data indicate that very few subsidized loans are given to children from families with high incomes.

[21] Without this debt consolidation, the state space of married couples would have two additional state variables (student debt of each spouse).

2. Marital Matching

Matching takes place at the same age (at the end of period $j = 3$) for everyone. Although men and women are heterogeneous in several dimensions upon entering the matching stage (education, ability, wealth, and productivity), we assume that (1) probabilistic matching between men and women is based on only education and (2) everyone marries. Matching rates in the model are based on observed CPS data, for which educational pairing frequencies are provided in table 1. The heavy weight on the diagonal is a manifestation of the pronounced assortative matching.

Our policy experiments modify the shares of men and women in each education group, which requires us to take a stand on how these changes affect the conditional matching probabilities. Our approach is to represent the observed matching matrix of table 1 with an assortative component and a random component, similar to Fernández and Rogerson (2001): with some probability, the individual is assigned to a partner of the same education level (or the closest level, if not enough partners of that education group are available in the marriage market) and with the complementary probability she draws randomly from the pool of available men. In counterfactual, we keep this probability constant, and we thus maintain the same degree of assortative matching. Online appendix B.2 explains this approach in detail.

We assume that the value of marriage is shared equally with full commitment ex ante and that there is no possibility of divorce.[22] Full commitment implies that the wealth levels of the two spouses after marriage are combined into a household wealth level. Online appendix B contains more details on the calculation of value functions at this stage.

3. Working-Age Families

In this stage, each family solves a standard life cycle problem akin to the one in equation (7). The key difference is that the choice variables include consumption and labor supply of both members of the household. The structure of the shocks is the same, with uncertainty over efficiency units of human capital for both husband and wife, as specified before. Total household expenditures allow for economies of scale, as specified in Section II.B. The couple's value function $W_j(\boldsymbol{x}_j)$, together with the relevant budget constraint, is shown in online appendix C.

[22] There are no singles in the model. Consequently, there is no well-defined outside option to marriage. If there was an alternative to marriage, then the sharing rule would be defined as a share of surplus computed on the basis of outside options. This would add the complexity of a heterogeneous and possibly age-varying Pareto weight in the case of limited commitment, i.e., two additional state variables for the couple.

TABLE 1
Husband-Wife Matching on Education

	Wife's Education		
Husband's Education	Less than High School	High School	College
Less than high school	.107	.030	.002
High school	.027	.498	.042
College	.002	.056	.236

Source.—Current Population Survey 2000.
Note.—Cell frequencies are the percentage of all marriages involving a particular match; i.e., these frequencies sum to 1.

The household problem becomes slightly different when the children (a pair) are born because parents know the gender of children right away, which adds a state variable from $j =$ (age) on. Parents do not know exactly what a child's cognitive and noncognitive skills will turn out to be yet, but they can forecast them on the basis of parental skills and education. Abilities and education preferences (the random component of the psychic shock) of a child are revealed to their parents at the stage when inter vivos transfers to the children are chosen. The household problem in the period of the inter vivos transfers is described in more detail in Section II.D.

4. Retirement

After inter vivos transfers have been made and children have left home, parents continue working until retirement age $j^{RET} - 1$. Once retired, they solve a simplified problem with labor supply fixed at zero. Their income is augmented by Social Security payments, which depend on the level of education. Retirees may die at age j with probability equal to the empirical mortality rates (US Life Tables 2000). We assume perfect annuity markets during retirement; thus, the return to saving is increased in line with the mortality rate for the relevant age because the assets of expiring households are redistributed within cohorts. We show the problem of retired households in online appendix C.

D. Intergenerational Linkages

The two crucial mechanisms for intergenerational linkages in our model are (1) the transmission of skills and (2) inter vivos transfers, both from parents to children.

1. Transmission of Abilities

We view skills as being formed during childhood and crystallized by age 16, the starting point for choices. Given the available data, we assume that cognitive and noncognitive skills are drawn from a joint distribution that depends on the mother's own cognition and her education. The dependence on mother's education endogenizes the intergenerational transmission of skills and reflects the dependence of investments in children on educational attainment of parents, which is consistent with the literature: Cunha and Heckman (2008) and Cunha et al. (2010) estimate that parental background and child investments have a strong effect on the development of child skills, while Carneiro, Meghir, and Parey (2013) find that both maternal education and Armed Forces Qualification Test (AFQT) scores are important determinants of child ability.

In counterfactual simulations, we assume that the relationship of skills with parental education, conditional on parental cognitive skills, can be taken as causal; hence, as the parents change their education choices as a result of policy, they affect child skills on the basis of our estimated relationship.[23]

2. Inter Vivos Transfers

Individuals start their life with some wealth and funding for their education, which is the result of parental transfers. To reduce the computational burden, we posit that each family has two identical children. Hence, the family makes the same transfers to each of them. The unconditional transfers $\hat{a}_0$ are paid to the child immediately, whereas the college-conditional transfers $\hat{a}^{CL}$ are committed to a trust account when the child is 16 and then paid to the child upon entering college at 18.

Utility from children and the resulting transfers arises from both altruism and paternalism. In what follows, we denote variables for the child with the caret symbol. The altruistic weight parents put on their child's expected lifetime utility is $\omega_{\hat{g}}$. Beyond altruism, parents may enjoy a utility gain ξ if their child goes to college, reflecting paternalistic preferences. This is an important feature that may explain why, in the data, lower-ability children of wealthier parents attend college. It is also relevant for the extent to which private transfers are (or are not) crowded out by government programs. The additional value that parents obtain from their children at the age where the latter start making their own choices is therefore given by

$$\omega_{\hat{g}} \mathcal{V}_{g0}\left(\boldsymbol{x}_0^*\right) + \xi \cdot \mathbb{I}_{\{\hat{e}=CL\}}, \tag{14}$$

where $\mathbb{I}_{\{\hat{e}=CL\}}$ indicates whether the child attends college. At the time of the transfer, parents know both the abilities of the child ($\hat{\boldsymbol{\theta}}$) and her random shock to education preferences ($\hat{\kappa}_\epsilon$), which are included in the

[23] Details on estimation of these transition matrices using the Children of the NLSY79 data are reported in Sec. III.

child's state variables $\boldsymbol{x}_0^*$. We allow altruism to depend on gender because we observe gender differences in inter vivos transfers; however, we restrict paternalism to be the same across genders because we do not observe gender differences in the influence of parental wealth on education.

Transfers are determined by augmenting the parent's value function by the value defined in equation (14) and maximizing with respect to the conditional and unconditional transfers, subject to the constraint that these amounts cannot be negative. The cost of the transfer to the parent is the reduction in their wealth. Gains from transfers accrue to the parents for two reasons. First, the children's value $\mathcal{V}_{g0}^*(\boldsymbol{x}_0)$ is increasing in $(\hat{a}_0, \hat{a}^{CL})$, and parents are altruistic. Second, a large enough conditional transfer $\hat{a}^{CL}$ can induce the child to choose to attend college, and since parents are paternalistic, they experience an extra utility gain ξ from this choice. Because of the fixed nature of the utility gain, this paternalistic motive is stronger for wealthy parents whose marginal utility from consumption is low. Thus to identify the parameters linking generations through altruism and paternalism, we will use data on inter vivos transfers as well as data on educational attainment by parental wealth and child ability. In particular, the rate of college attendance for lower-ability children is driven exclusively by parental wealth, and this feature helps distinguish pure altruism from paternalistic preferences for college attendance.

The formal structure of the dynamic problem of the family in the period of the inter vivos transfers is presented in online appendix C, and details of the estimation of altruism and paternalism parameters are contained in Section III.

E. Equilibrium

We solve for the stationary equilibrium of our economy numerically. In equilibrium, individuals maximize their expected lifetime utility by choosing their education level, federal loans as college students, consumption and saving, labor supply, and inter vivos transfers to their children. Firms maximize profits by choosing capital and labor inputs. Prices clear all markets. The government budget constraint is balanced period by period. Stationarity implies that the cross-sectional allocations for any given cohort of age j are invariant over time. A detailed definition of the stationary equilibrium and its numerical computation is presented in online appendix C.

III. Estimation Results

There are three sets of parameters in the model: those that we fix externally on the basis of the literature, such as the intertemporal elasticity of substitution for consumption and labor supply (for a complete list, see table A1); those that are estimated separately, namely, the production function, the wage process, and the intergenerational transmission of abilities; and those that are estimated within the equilibrium model using the method of moments, conditional on the two previous sets. This last group includes parameters determining the psychic costs of education, some preference parameters (including the discount factor, altruism, and paternalism), and several others, listed in table A2.

In what follows, we discuss in more detail the estimation strategy and results for the second set of parameters and for the psychic costs, altruism, and paternalism parameters.

A. Aggregate Production Function

Recall our aggregate technology specification in equations (3) and (4). Under the assumption that all labor markets are competitive, we estimate the technology parameters and test the isoelasticity assumptions using CPS data on wage bills and hours worked for the different gender-education groups for the years 1968–2001. Details of our estimation and tests, including robustness checks using different instruments and specifications, are presented in online appendix D.

In the numerical analysis, we set the elasticity of substitution between education aggregates to 3.3 (i.e., $\rho = 0.7$). This is within the range of our estimates and in line with values reported in the literature.[24] Our specification of technology also allows for imperfect substitutability of male and female efficiency units.[25] We use a baseline value of $\chi = 0.45$ in the numerical simulations, corresponding to an education-conditional elasticity of roughly 1.8 between men and women, a number within our range of estimates. The values of the gender/education CES weights $s^{g,e}$ are reported in online appendix D.[26]

[24] Many estimates in the literature are based on a coarser two-type skilled/unskilled classification for labor, with no gender differences. Katz and Murphy (1992) estimate the elasticity of substitution to be 1.41; Heckman et al. (1998a) report a favorite estimate of 1.44. Card and Lemieux (2001) obtain an elasticity of substitution between college and high school workers of about 2.5; however, their estimated elasticity, when accounting for imperfect substitutability across age groups, ranges between 4 and 6. Finally, using a nested specification with three human capital types, Goldin and Katz (2007) suggest a preferred elasticity between college and noncollege workers of 1.64.

[25] Existing evidence suggests that equally skilled individuals of different gender are not perfect substitutes; see, e.g., Johnson and Keane (2013).

[26] Our production function specification does not display capital-skill complementarity. Krusell et al. (2000) find evidence of complementarity between equipment capital (but not structure) and college-educated workers. Given the richness of the household side of the model, we chose to maintain the production side as relatively stylized and opted for one type of capital. In our policy experiments, the aggregate capital stock changes very little (policy changes affect the saving behavior of only the wealth-poor, who account for a small share of aggregate wealth). Therefore, the additional effect of changes in capital on the college premium would be fairly small with capital-skill complementarity.

This specification of aggregate technology, together with the equilibrium selection mechanism of the model, yields college and high school wage premia that are consistent with the data. Applying the estimation approach of Goldin and Katz (2007) to data simulated from our model, the log college/high school wage differential is estimated to be 0.58, and the high school graduate/less than high school log wage differential is 0.37. These values are close to the estimates presented by Goldin and Katz (2007, table A8.1) for the year 2000, who place the college premium between 0.58 and 0.61 and the high school premium between 0.26 and 0.37. When we examine gender gaps, recent work by Goldin (2014) indicates that median full-time earnings of women (in the year 2000) were roughly 74 percent those of men, and our model generates a corresponding figure of 73 percent.

B. Wage Process and the Impact of Ability on Earnings

The wage process is an important ingredient of the model because it determines the career profile as well as the amount of uninsurable uncertainty faced by individuals. We allow individual wage dynamics to depend on age, gender, education, and abilities. Heckman, Stixrud, and Urzua (2006b) document that the effects of cognitive skills on earnings are four to five times larger than those of noncognitive skills. In light of this finding, we make the simplifying assumption that only cognitive ability directly affects earnings in the labor market.

The idiosyncratic labor productivity process $\varepsilon_j^{g,e}$ is specified as (dropping the individual subscript i to ease notation)

$$\log \varepsilon_j^{g,e} = \lambda^{g,e} \log \theta_{cog} + A_j^{g,e} + z_j^{g,e}, \tag{15}$$

where $A_j^{g,e}$ is the gender- and education-specific deterministic age profile (proxied by a quadratic polynomial) and

$$\begin{aligned} z_j^{g,e} &= \varrho^{g,e} z_{j-1}^{g,e} + \eta_j^{g,e}, \\ \eta_j^{g,e} &\overset{iid}{\sim} N(0, \sigma_\eta^{g,e}). \end{aligned} \tag{16}$$

The initial value $z_0^{g,e}$ is drawn from a normal distribution with mean zero and variance $\sigma_{z_0}^{g,e}$. The impact of cognitive skills on wages $\lambda^{g,e}$, the persistence of idiosyncratic productivity shocks $\varrho^{g,e}$, and the variance of idiosyncratic productivity innovations $\sigma_\eta^{g,e}$ all vary by gender and education attainment. This heterogeneity in returns to schooling will in part drive differences in education choices between men and women and across ability groups.

We estimate wage processes correcting for selection into work, which provided significant adjustments for women but not for men. In online appendix E, we discuss aspects of the estimation and report the resulting deterministic age profile for each education group, which is by now standard: the higher the level of education, the steeper the increases of wages with earnings.

The estimates of the ability gradient and the stochastic process of the shocks are reported in tables 2 and 3, respectively. The ability gradient for wages increases with education, implying a strong complementarity between the two. It is also the case that the returns to ability increase by more for women than for men, particularly at lower education levels. Shocks are highly persistent and close to being a random walk for all but females with less than high school. Notably, even for given ability, the variance of initial productivity draws increases with education for women and even more so for men. This uncertainty is particularly difficult to insure against, since at young ages individuals tend to be wealth-poor.

C. *Intergenerational Transmission of Cognitive and Noncognitive Skills*

To measure the transmission of cognitive and noncognitive skills between generations, we use data from the Children of the NLSY79 survey, which provides test scores of cognitive skills and education for mothers as well as cognitive and noncognitive skills for children. We approximate noncognitive skills using the first principal component factor among five measures from the behavioral problems index (antisocial, anxiety, headstrong, hyperactive, and peer conflicts). Children's cognitive skills are measured as the first principal components among Peabody Individual Achievement Test math, reading recognition, and reading comprehension scores. Mothers' cognitive skills are approximated by AFQT scores. Mothers are also classified into three education attainment levels.

We begin by grouping individuals into terciles of each skill variable (mother and children separately). The discretization of skills and the level of detail we choose is designed to make the computational problem tractable. Having discretized skill levels in this way, we characterize each mother by an education/cognitive achievement pair and each child by a cognitive/noncognitive achievement pair. In this way we are able to estimate a 9×9 transition matrix Γ_θ of empirical frequencies, linking mothers'

TABLE 2
Estimated Ability Gradient $\lambda^{g,e}$ (NLSY79)

Education Group	Male Gradient	Female Gradient
Less than high school	.428 (.054)	.184 (.057)
High school graduate	.517 (.030)	.601 (.036)
College graduate	.797 (.109)	.766 (.099)

Note.—Standard errors are in parentheses.

TABLE 3
STOCHASTIC PROCESS OF WAGES

	Less than High School		High School Graduates		College Graduates	
	Parameter	Value	Parameter	Value	Parameter	Value
			A. Males			
Persistence	ϱ^m	.955 (.010)	ϱ^m	.952 (.005)	ϱ^m	.966 (.015)
Permanent shock	σ^m_η	.015 (.002)	σ^m_η	.017 (.001)	σ^m_η	.017 (.005)
Initial dispersion	σ^m_{z0}	.037 (.005)	σ^m_{z0}	.059 (.003)	σ^m_{z0}	.094 (.009)
			B. Females			
Persistence	ϱ^f	.852 (.023)	ϱ^f	.953 (.003)	ϱ^f	.983 (.016)
Permanent shock	σ^f_η	.026 (.005)	σ^f_η	.019 (.001)	σ^f_η	.018 (.004)
Initial dispersion	σ^f_{z0}	.035 (.011)	σ^f_{z0}	.041 (.003)	σ^f_{z0}	.076 (.007)

NOTE.—Shown are estimates of parameters of the process for individual efficiency units $\varepsilon^{g,e}_j$ (NLSY79). The σ parameters denote variances of the respective shock. Standard errors are in parentheses. Data are in annual frequency.

education and cognitive skills to the cognitive and noncognitive achievement of their children. The entire transition matrix is reported in online appendix table F.1. In table 4 we summarize the full transition matrix by reporting the distribution of child cognitive outcomes conditional on maternal cognition tercile and education. A mother's education and cognition are both important for her child's cognitive skills. These results confirm the presence of a strong relationship between maternal inputs and child skills, as documented in papers already cited above.

D. *The Method of Moments Estimation*

Table A1 lists parameters that we set in advance. Given these parameters as well as the production function, income processes, and transition matrices for intergenerational transmission of cognitive and noncognitive skills that we have just discussed, we estimate the remaining parameters by minimizing an unweighted quadratic distance criterion between data moments and corresponding moments implied by the model. The moments implied by the model can be computed explicitly without simulation, exploiting the fact that we discretize the state space. We then use the efficient global optimization algorithm (Jones, Schonlau, and Welch 1998), which is derivative free, saving computational time in practice. In what follows we discuss results on psychic costs of education and intergenerational linkages in preferences.

Table A2 shows the remaining estimated parameters with corresponding standard errors (computed with preset and preestimated parameters

TABLE 4
Ability Transition Probabilities by Mother's Education and Ability

Mother's Education and AFQT Tercile	Child Cognition Tercile		
	1	2	3
Less than high school:			
1	.446	.321	.232
2	.412	.332	.255
3	.343	.346	.311
High school:			
1	.364	.343	.293
2	.319	.347	.334
3	.298	.346	.356
College:			
1	.320	.347	.333
2	.260	.339	.402
3	.224	.324	.452

Note.—Shown is the cognitive achievement of children conditional on mother's education and AFQT tercile (lowest = tercile 1; highest = tercile 3).

taken as given), and tables A3–A6 show the fit of the model with respect to the distribution of educational attainment by parental wealth and cognitive skills.

E. Psychic Cost of Education

Schooling is determined by the discrete choice problems in equations (6) and (8). Variability in educational attainment by cognitive and noncognitive skills, for which we have measures, helps identify ς_2^e and ς_3^e. The expression for the psychic costs of education also includes the parameter ς_4^e, which defines the variance of unobserved shocks to the costs of education. This raises an identification question: normally in a discrete choice model this scale parameter would not be identified, which would mean that the psychic costs of schooling would be identified up to scale only. Here, however, the choice between education levels depends on the expected value implied by each educational option. These value functions have a scale that is entirely determined by the flow of leisure and consumption.[27] In other words, once we specify a preference class and assign values to its parameters, value functions are completely determined, including their scale. Moreover, these values enter the education choice with a unit coefficient and thus determine the scale of the psychic costs in the same util units in which the values themselves are defined (see eqq. [6], [8]).[28]

[27] Obviously, a convenient but innocuous normalization is implicit in the model to convert dollars into units of the final good, whose price is set to 1.

[28] See also Cunha et al. (2005), Heckman and Navarro (2007), and Eisenhauer, Heckman, and Mosso (2015) for identification issues of dynamic discrete choice models.

The parameters of the psychic costs of education are presented in table 5. In interpreting these values, note that all right-hand-side variables are standardized to have unit variance and mean zero.

Being a woman increases the cost of high school but has no significant effect on college psychic costs, although the point estimate is negative. Noncognitive and cognitive skills reduce costs of education. Cognitive skills have a particularly important effect in reducing costs of college.

In table 6 we present the value of psychic costs for high school graduates and college graduates. These are the total realized costs for completing the respective level of education born by those making this choice. These numbers are thus lower than the corresponding population ones because of self-selection. As already discussed, the psychic costs include an observable and an unobservable component. The explained variance (R^2) for high school graduates is 60.5 percent of the total, while for college graduates it is 37.3 percent. Thus, while measurable cognitive and noncognitive skills play an important role, there is a large part of the psychic costs of education that remains unexplained, particularly for college, as also found by Eisenhauer et al. (2015), among others.

F. Altruism, Paternalism, and Inter Vivos Transfers

The NLSY97 provides information on family transfers received by young individuals. In particular, it asks respondents about any gifts in the form of cash (not including loans) from parents. Online appendix G describes the sample we construct and the methodology we use to measure early inter vivos transfers, and it reports basic facts about parental gifts to young individuals, as recorded in the NLSY97. Since we model early inter vivos transfers as one-off gifts from parents to children occurring before college age, we restrict attention to the cumulative transfer between ages 16 and 22. In our calculations we also include imputed rents for students living in their parents' home.[29]

In the data, we observe male children receiving somewhat larger transfers than female children. The average transfer gifted to a male child is just above $33,000, while the average transfer gifted to a female child is around $29,000.

Paternalistic preferences for college, beyond pure altruism, may motivate wealth transfers. To help identify the effect of paternalism, we use information about the relative college attainment rate of children from wealthy and high-income families relative to poorer families for different ability levels of the children. College attainment in the NLSY97 is strongly

[29] We find that the coresidence component makes up a large fraction of the total inter vivos transfers, as also emphasized by Johnson (2013).

TABLE 5
Parameters of Psychic Cost Functions

Parameter	High School Coefficient	High School Marginal Effect	College Coefficient	College Marginal Effect
ς_0^e (constant)	.6501		.8244	
	(.0208)		(.0261)	
ς_1^e (female)	.1133	−.076	−.0313	.017
	(.0121)		(.0196)	
ς_2^e $(\log(\theta_{non})/\sigma_{non})$	−.0608	.050	−.0670	.035
	(.0081)		(.0124)	
ς_3^e $(\log(\theta_{cog})/\sigma_{cog})$	−.0896	.075	−.1621	.086
	(.0349)		(.0335)	
ς_4^e (κ_ϵ)	.1270	−.093	.3342	−.19
	(.0221)		(.0317)	

Note.—When coefficients are negative, it means that increasing the corresponding variable reduces the psychic costs of education. Reported marginal effects are changes in the proportion attending the respective education level (high school or college) as a result of increasing the corresponding right-hand-side variable by 1 standard deviation in the psychic costs function for that education level only and keeping everything else the same. For the case of "Female," the marginal effect corresponds to changing male preferences to be identical to females. Asymptotic standard errors are in parentheses.

and positively correlated with reported parental income and net worth. For example, children whose parents are in the fourth quartile of the wealth distribution are nearly three times as likely to become college graduates as those whose parents are in the first quartile. More importantly, low-ability children from wealthy families are much more likely to attend college than similar children from less wealthy families. This difference helps identify paternalistic preference. Among the estimation moments, we include the fractions of college graduates and those with less than high school within each parental wealth quartile and parental income quartile.

The resulting estimated altruism parameters are $\omega_{\hat{m}} = 0.518$ (standard error = 0.107) for males and $\omega_{\hat{f}} = 0.470$ (standard error = 0.076) for females, showing a small preference for boys that translates into some

TABLE 6
Psychic Costs of Education Expressed as Percentage of Average Life Cycle Consumption ($583,000)

	High School	College
Average in population	9.4	20.1
Average among graduates	8.9	13.5
Explained variance (R^2)	60.5	37.3

Note.—Explained variance relates to the proportion of the population variance of psychic costs accounted for by the observable variables: cognitive skills, noncognitive skills, and gender. Psychic costs of college include the cost of completing both high school and college.

gender differences in inter vivos transfers across counterfactual policy experiments.[30]

The paternalism parameter is estimated to be $\xi = 0.28$ (standard error = 0.04), which corresponds to a parental willingness to pay for college attendance of the child of $21,500 on average, or 3.7 percent of average life cycle consumption. The economic importance of this parameter can be seen in the fact that in our model about 30 percent of college graduates receive conditional transfers from their parents. Among students receiving conditional transfers, two-thirds have parents in the top quartile of net worth, and the remaining one-third have parents in the third quartile of net worth. Without the paternalistic preference for college, the model would not be able to explain the extent to which college attainment rates among children of wealthy parents exceed those among children of poorer parents, particularly for lower-ability children.

IV. Implications of the Model

We examine the behavior of the model along six dimensions. First, we analyze the implied life cycle profiles for hours worked, earnings, consumption, and wealth. None of these moments are explicitly targeted in the parameterization (only those for wages are). Second, we study the determinants of parental transfers to children. Third, we measure the degree of intergenerational persistence of educational attainment and income in the model (also not targeted). Fourth, we examine the role of parental wealth in determining educational achievement. Fifth, we reinforce the empirical plausibility of the model by simulating an artificial randomized experiment where a (treatment) group of high school graduates receives a college tuition subsidy and a (control) group does not. This last simulation shows that the elasticity of college attainment with respect to tuition in our model is comparable to estimates from the empirical literature on schooling. Finally, we assess the role of assortative matching in determining the return to education and other aggregate equilibrium outcomes. In online appendix H we show that the model also provides reasonably good out-of-sample predictions on college attendance rates and wage premia when extrapolated to the year 2010.

A. Life Cycle Profiles

Figure 1 plots averages and dispersion of log earnings, log consumption, and wealth over the life cycle for our three education groups. It also reports log hours worked separately by gender.

[30] Imposing an equal parameter for altruism between genders would, however, fail to fully close the $4,000 gap in transfers estimated in the data, suggesting that this difference has more to do with heterogeneity in market returns.

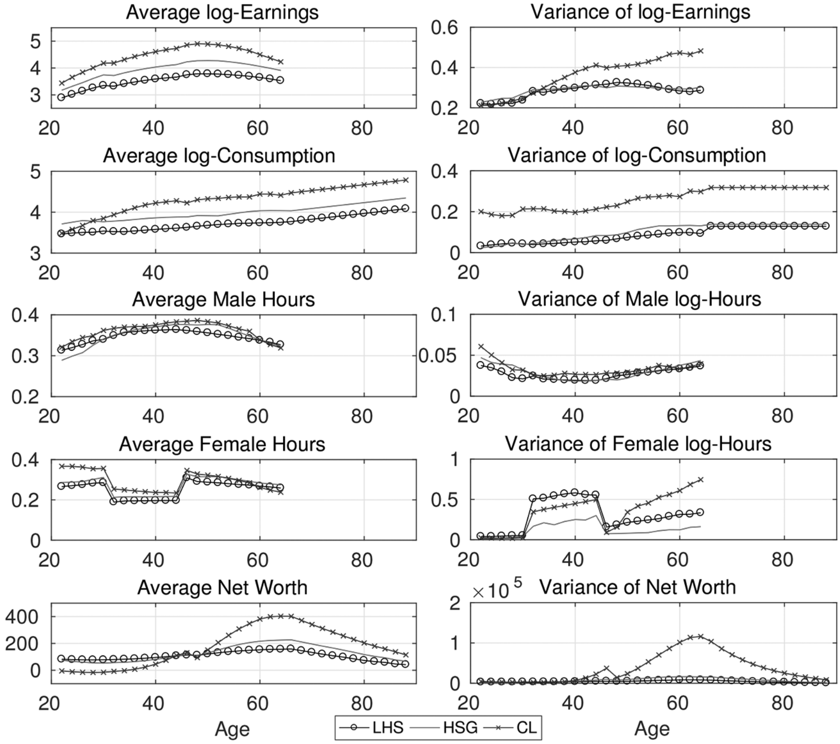

Fig. 1.—Statistics presented by education. Lines marked with crosses are headed by a college graduate, and those marked with circles are headed by someone with less than a high school degree. For family-level variables (consumption and wealth), the education of the head (male) is used for classification. Color version available as an online enhancement.

Average hours worked by men follow a canonical hump shape over the life cycle, which is a reflection of the hump shape in the exogenous age-productivity profiles. There is considerable dispersion in the early career hours of men, followed by a steady rise from the early thirties to retirement. As expected, women's hours worked exhibit changes because of the presence of children in the household. Average female hours fall as preferences for nonmarket time increase during child-raising years. The dispersion of hours also increases during this period because female labor supply elasticities are larger with children.

The rise in average earnings over the life cycle is more pronounced for more educated households, and the changes in the variance of log earnings between ages 25 and 60 are quantitatively consistent with empirical evidence (e.g., see Guvenen 2009, fig. 4).[31]

[31] Households are categorized by the highest education within a household.

A comparison between consumption and earnings paths (both their mean and dispersion) reveals that consumption smoothing through borrowing and saving is quite effective after the schooling phase. During working life, the variance of log consumption grows 0.1 log points for college graduates and a bit less for households with less educated heads. These changes compare with a rise twice as large in the variance of households' log earnings. During retirement, the combination of annuity markets and interest rate above the discount rate implies a linear upward-sloping consumption pattern and constant dispersion in logs.

Wealth accumulation features the typical hump-shaped pattern. In the model, the drop in household wealth at age 48 arises as a consequence of the inter vivos transfer to children. The drop is much larger for the highly educated families, whose children are the most likely to attend college. Young college students and college graduates decumulate their wealth and borrow to enroll in college and to smooth consumption in their first years of working life.

B. Determination of Inter Vivos Transfers

Several forces shape parental decisions on how much to transfer to their children. The first purpose is to narrow the gap between parent's and child's lifetime utilities, and the extent to which parents want to close this gap depends on the degree of altruism ($\omega_{\hat{g}}$). This motive (intergenerational smoothing) is strongest for low-ability and low-earning-potential children, especially those with rich parents. Paternalism, as explained, pushes in this same direction. The second purpose is to alleviate the financial constraints of children in the event that they choose to go to college. This second motive (college education financing) is strongest for high-ability children whose return to attending college is the highest.

The left panel of figure 2 shows that in the model, inter vivos transfers increase monotonically with parental wealth at the age of the transfer (age 48). For some poor families (about 15 percent in our model), the marginal cost of transferring to the children is too high in terms of their own foregone consumption, and they make no transfer.[32] Finally, this plot also shows that for given wealth, highly educated parents save more for the inter vivos transfers, as they expect their children to be on average of a high-ability type as well, therefore with large gains from college education. The right panel of figure 2 shows that transfers tend to be increasing in the ability of the child (holding the parents' abilities constant) because greater financial resources are needed to pay for education.

[32] Indeed, in many cases, parents would be better off with a negative transfer (i.e., receiving a transfer from their child) because they expect their child to earn more eventually.

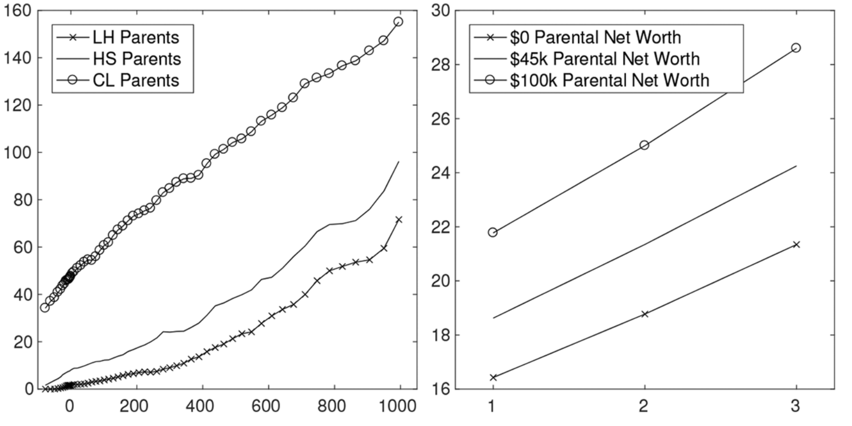

FIG. 2.—Parental transfers to children as a function of household head's education and parental wealth (*left*) and parental wealth and child's ability (*right*).

C. *Intergenerational Persistence of Education and Income*

The model generates a realistic intergenerational correlation of college attainment. In the model, 50.0 percent of those whose mother is a college graduate and 47.4 percent of those whose father is a college graduate become college graduates themselves. Furthermore, 52.1 percent of those for whom both parents are college graduates become college graduates themselves. Although these statistics are not targeted in the estimation, we do well in replicating patterns observed in data. For example, in the NLSY79, 47.2 percent of children whose mother is a college graduate also attain a college degree, while 55.3 percent of those for whom both parents are college graduates attain a college degree.

The model is able to replicate these high degrees of persistence in part because it includes cognitive and noncognitive skills and paternalism. The skills are important both directly and indirectly: directly because parental cognitive skills in part determine the children's cognitive skills, which in turn drive college attendance and wages, and indirectly because parental education leads to the improvement of child skills, which in turn reduces the psychic costs of college for children of educated parents. Paternalism increases the tendency for rich parents to send their child to college, further increasing persistence.

We also evaluate model performance in terms of intergenerational income persistence. Chetty et al. (2014) use Internal Revenue Service (IRS) tax data to study the relationship between the mean child income rank and parents' income rank for cohorts of children born between 1971 and 1986 and estimate a linear regression slope between 0.25 and 0.35 for male children, depending on the birth year. We repeat this exercise on our simulated data, with the same definition of pretax household income averaged over ages 31–46 for both children and parents, and find a slope of 0.33, thus within the above range. Furthermore, as can be seen in figure 3, we find that a child's expected income rank is well approximated by a linear function of their parent's rank in our model, just as Chetty et al. (2014) find in IRS data. Note, however, that below the 20th percentile of income we observe a steeper slope of about 1.0.

The more traditional intergenerational log-log earnings correlation in our simulated sample is 0.34. Jantti et al. (2006) estimate this elasticity for the United States at 0.36, and similar values are found by Solon (1999).

D. *Parental Wealth and Educational Achievement*

In this section we examine the relative roles of family background and cognitive ability in the determination of education outcomes.

First, we analyze the correlation between cognition, wealth and income across households to make sure that in our model parental skills and parental resources are distributed as in the data. Zagorsky (2007) uses the 2004 module of the NLSY79 to estimate a correlation between income (net worth) and AFQT scores of 0.30 (0.16) in a sample of individuals ages 40 and 47. In our benchmark simulation, the correlation between income (wealth) and cognitive ability θ_{cog} for the same age range is similarly 0.30 (0.24).

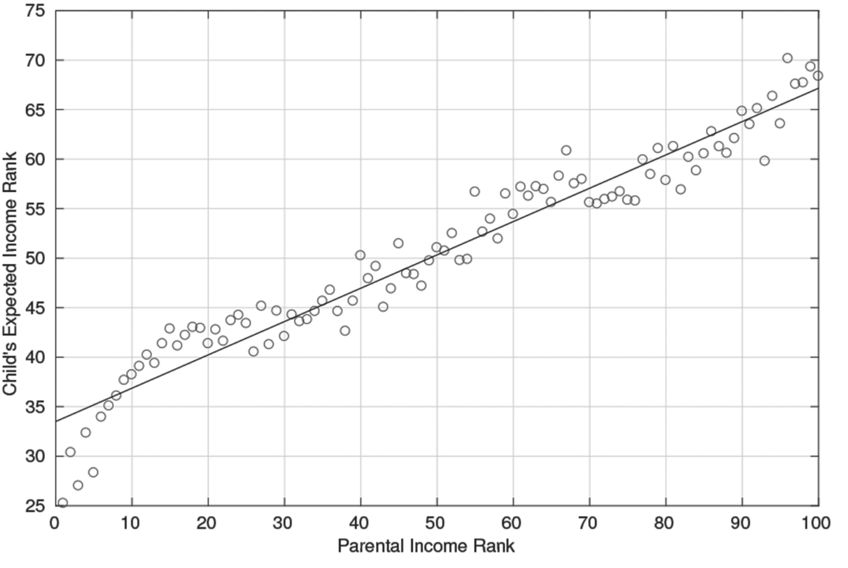

Fig. 3.—Intergenerational rank-rank regression

Next, we plot a bar graph that displays college graduation rates by child's ability tercile and by parental net worth quartile in the model. Figure 4*A* shows a positive gradient in both dimensions, a feature that is very similar to the findings of Belley and Lochner (2007).

A striking feature of this plot is the large role played by parental wealth at every ability level. Even among higher-ability children, parental wealth plays an important role, with 40 percent college attendance for those whose parents are in the lowest quartile of wealth, increasing to 70 percent attendance for the top wealth quartile. Among the lowest-ability children, almost none attend college unless their parents are from the highest wealth quartile. Paternalism plays a key role in generating this pattern in the model: wealthy parents induce children with lower ability to attend college.[33]

The importance of paternalism becomes especially evident in figure 4*B* and 4*C*, where we plot the financial returns (fig. 4*B*) and the total returns (financial returns net of the monetized value of the psychic cost; fig. 4*C*) for those graduating by parental wealth and child ability.

The financial returns are computed by calculating the proportion of consumption that would have to be given to individuals who graduate from college in the model if they instead had not enrolled in college in order to make them indifferent between the two choices. Specifically, the financial return is the number φ that solves the following equation:

$$\sum_{g=m,f}\int_{S_1^{g,*}} V_{g1}^{*}\left(\boldsymbol{c}^{CL}, \boldsymbol{l}^{CL}; \boldsymbol{x}_1^{*}\right) d\mu_1^{g,*} = \sum_{g=m,f}\int_{S_1^{g,*}} \mathbb{E}_z\left[V_{g1}^{HS}\left((1+\varphi)\boldsymbol{c}^{HS}, \boldsymbol{l}^{HS}; \boldsymbol{x}_1^{*}, z\right)\right] d\mu_1^{g,*}. \tag{17}$$

The left-hand side is simply the expected value of a college degree for all those who optimally choose to attend. The right-hand side is the counterfactual expected value if the same set of individuals (distributed accordingly to $\mu_1^{g,*}$, the distribution of college students at $j = 1$) had started working as high school graduates instead of going to college. Note that on the right-hand side we also need to integrate over initial productivity. The sequences $\boldsymbol{c}^e$ and $\boldsymbol{l}^e$ are the state-contingent life cycle consumption and leisure plans of such individuals as college- and high school–educated workers. Conditional inter vivos transfers are given to individuals also in the counterfactual, thus they do not affect the calculation of returns. Financial returns to college thus capture (1) the additional consumption associated with the college wage premium, (2) the consumption-equivalent value

[33] Indeed, among the lowest-ability group, all college graduates receive conditional transfers that compensate them for this loss. In the middle-ability group, 50 percent of those from the two lower-wealth groups receive such transfers and 60 percent of the two higher groups. Finally, among the highest-ability group, 20–30 percent receive conditional transfers, with the wealthier group transferring more, conditional on attendance, as we would expect.

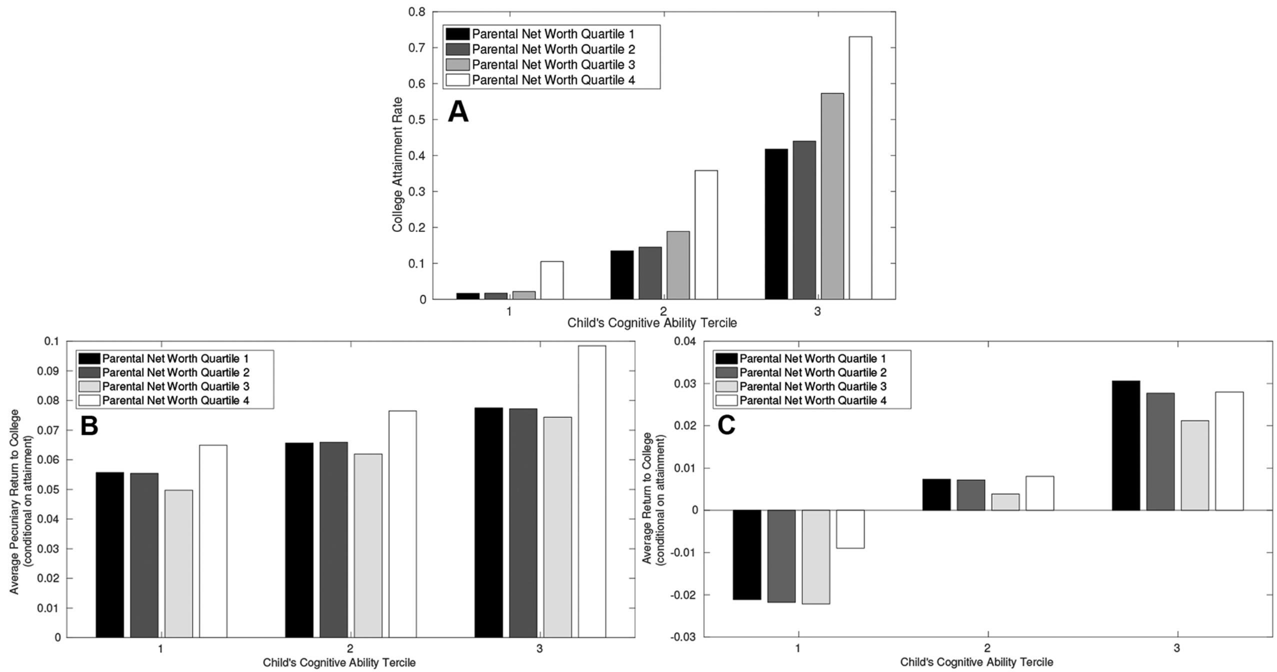

Fig. 4.—College attainment and returns to college for graduates by ability and parental wealth: model simulations. *A*, College attainment rate. *B*, Financial returns to education. *C*, Total returns to education. In calculating the returns, parental transfers are held constant at the amount the student would receive if attending college, which is why the returns we show can be negative for those attending college.

of being more likely to meet a college-educated partner on the marriage market, and (3) the additional consumption-equivalent value (through altruism and paternalism) of being a college-educated parent and thus having children with better skills and better economic outcomes. To compute total returns (as opposed to simple financial ones), we subtract $\kappa_g^{CL}(\boldsymbol{\theta}, \kappa_\epsilon)$, the additional psychic costs incurred due to college attendance, from the college value function inside the integral on the left-hand side. Thus, total returns also incorporate the consumption-equivalent value of the psychic cost.

The financial returns are always positive and increasing by ability, ranging from 5 percent in the lowest-ability group to 10 percent in the highest-ability one.[34] What is striking, however, is that the total returns are negative for those in the lowest-ability group once psychic costs are taken into account. Those from this group who attend college do so only because of the conditional parental transfers due to paternalism.

E. *Tuition Elasticity of College Attainment*

The simulated response of aggregate college attainment to a small change in tuition fees is also similar to responses measured in actual data. To measure this response in our model, we perform a partial equilibrium simulation in which we reduce tuition fees by $1,000 per year just before a single cohort of children make their education decisions.[35] The aggregate graduation rate of this cohort increases by 3.95 percentage points.

This response is consistent with existing empirical evidence. Deming and Dynarski (1995) and Kane (2003) provide a synopsis of the empirical estimates from similar quasi-natural experiments in which a discrete change in aid policy affects one group of individuals but not others, and they conclude that enrollment into college by high school graduates benefitting from an additional tuition grant of $1,000 rises between 3 and 5 percentage points.[36] Other studies use cross-state variation in tuition costs to estimate that enrollment would rise by 4–6 percentage points per $1,000 reduction in tuition costs (Kane 1994; Cameron and Heckman 1998).

F. *Marriage Market*

The marriage market plays an important role in our model. The education of the partner has an impact on the human capital of children both directly

[34] The effect of parental wealth on these returns reflects different selection into college.

[35] This is the partial equilibrium version of our $1,000 grant expansion counterfactual, reported in Sec. V.C.

[36] Among the policy changes surveyed in these studies, the closest to our simulated experiment are the Georgia Hope Scholarship program, the Social Security Student Benefit program, the DC Tuition Assistance Grant program, the Cal Grant program, and other similar examples of discontinuities in fellowship eligibility at individual institutions.

(through the mother) and indirectly through wealth. Thus, the amount of marital sorting affects the intergenerational transmission of ability and of wealth. To illustrate the practical importance of these features, we conduct two extreme counterfactual simulations in which (1) we impose random matching and (2) we impose perfectly assortative matching.[37]

The results in table 7 confirm that the structure of the marriage market plays a significant role for economic outcomes. Moving from current levels of assortativeness to random matching would imply declines in welfare, output, and educational attainment, particularly for women. Moving to perfect sorting has opposite but smaller effects because the baseline economy is quite assortative in the first place.

V. Policy Experiments

In this section we conduct two sets of policy experiments. The first is aimed at assessing the role of the existing federal financial aid system—loans and grants—while the second examines the effects of marginal expansions in financial aid.[38]

Our main focus will be on the long-run responses, which allow parental transfers and factor prices to change as well as budget balancing fiscal adjustments to take place. All these components are important because they can mitigate the effects of policy. At the same time, the long-run equilibrium also allows for changes in the distribution of ability through the impact of education on cognitive and noncognitive skills, which may in turn reinforce policies that encourage education.

We present our results in two steps. The first step, which we call partial equilibrium short run, computes changes in outcomes of interest for the first affected cohort, holding prices and fiscal variables constant. The policy announcement is made just before parents choose their inter vivos transfer; hence, this experiment incorporates only the short-run behavioral response of parents (e.g., transfers) and children (e.g., labor supply in college) to the policy. We then consider an experiment we call general equilibrium long run, in which we compute the long-run steady state with new market clearing prices and the new stationary distribution of individuals across education, wealth, and ability. Government expenditures G are held constant in this experiment; thus, in this latter experiment adjustments of marginal labor income tax rates are required to balance the government's budget. Note that in such an economy with liquidity constraints and uninsurable idiosyncratic risk, it is not obvious whether expanding

[37] We can do this by manipulating the matrix governing assortativeness, as explained in Sec. II.C.2.

[38] In all policy experiments, we assume that college fees do not change and that financial markets do not offer new or modified loan products.

TABLE 7
Marriage Market Sorting (Random or Perfect) and Economic Outcomes

Outcome	Marital Sorting: Random	Marital Sorting: Perfect
College graduates (percentage points):		
Males	−.76	.3
Females	−1.2	.5
Output (%)	−.73	.27
Welfare (%)	−.54	.35

Note.—Shown are changes from the baseline economy.

(cutting) federal aid programs will require a higher (lower) tax rate on labor. For example, broadening these programs can be self-financing through a wider tax base, particularly with imperfectly substitutable human capital aggregates (for a discussion of these issues, see Findeisen and Sachs [2015]).

A key aspect of the results from our general equilibrium experiments is the analysis of welfare changes induced by the policy reform. We express these changes as a percentage of lifetime consumption for a newborn economic agent (an individual at age $j = 0$) behind the veil of ignorance with respect to her initial conditions (wealth and ability). To understand what drives the total welfare effect, we decompose it into three separate components: (1) a level effect on average consumption, (2) an uncertainty effect due to changes in the volatility of individual consumption paths, and (3) an inequality effect due to changes in the distribution of initial conditions. In online appendix I we provide a derivation of this welfare decomposition that builds on Benabou (2002).

A. *Value of Existing Federal Aid Programs*

In this section we explore how equilibrium outcomes would change in the model if federal aid programs were entirely removed from our benchmark representing the US economy. Key results are shown in table 8. A variety of additional results are reported in online appendix J. Moreover, in online appendix K we assess the robustness of the grant and loan removal experiments under fixed interest rates (an open economy model) and for different values of the elasticity between human capital aggregates.

1. Removing Tuition Grants

Removing tuition grants induces a noticeable reduction in college attainment in the long run. The loss of college students is partly mitigated by equilibrium price adjustments. As shown in panel A of table 8, attainment

TABLE 8
Removal of Existing Federal Aid Programs from Benchmark Economy

	Benchmark	Partial Equilibrium Short Run	General Equilibrium Long Run
	A. Removal of Grants		
College graduation rates:			
Men	.294	.212	.268
Women	.282	.210	.248
Top one-third of cognitive skills:			
Men	.538	.426	.504
Women	.519	.418	.474
Total:			
Top one-third of parental wealth	.399	.385	.467
Bottom one-third of parental wealth	.205	.073	.104
Other statistics:			
Crowding out of inter vivos transfers ($):			
Male	. . .	+2,502	+685
Female	. . .	+2,681	−776
Student labor supply (%)	. . .	+5.85	+.62
Aggregate output (%)	. . .	. . .	−1.97
Welfare gain (%)	. . .	. . .	−2.81
	B. Removal of Student Loans		
College graduation rates:			
Men	.294	.191	.267
Women	.282	.194	.248
Top one-third of cognitive skills:			
Men	.538	.377	.488
Women	.519	.383	.476
Total:			
Top one-third of parental wealth	.399	.383	.479
Bottom one-third of parental wealth	.205	.046	.076
Other statistics:			
Crowding out of inter vivos transfers ($):			
Male	. . .	+5,486	+4,645
Female	. . .	+5,214	+2,105
Student labor supply (%)	. . .	+5.08	+6.69
Aggregate output (%)	. . .	. . .	−1.98
Welfare gain (%)	. . .	. . .	−2.84

in the short-run partial equilibrium scenario would be roughly 7.5 percentage points lower. In general equilibrium, this scarcity effect puts upward pressure on the college premium, which in turn induces a compensating rise in college graduation rates. The final long-run general equilibrium drop in college attainment is almost 3 percentage points, still a sizable magnitude.

This drop in attainment comes about with significant alterations in the composition of the college student body. Skill quality is lower and family wealth becomes more important for college selection, as some able children from poorer families no longer find it feasible and/or optimal to attend college: college attainment in the lowest wealth tercile drops about three times as much as it does in the entire population.

Students are forced to gather additional resources through an increase in their labor supply while in college: in the long run, student labor supply grows by 0.6 percent. However, most of the adjustment occurs through parental transfers. In partial equilibrium, families increase transfers to their college-bound children by about $2,500 on average; however, in the long run, parental transfers increase by only $685 relative to the benchmark because parental incomes and wealth fall.[39]

Wealth-poor ($q = 1$) families are the most affected by removal of grants, and they are able to compensate for only a fraction of this loss: online appendix table J.6 shows that in the long run such families increase transfers to college-bound children by about $3,250 total, whereas the students' grants have been cut by $2,800 per year (i.e., $11,200 total). In turn, students from wealthy backgrounds increase their college participation relative to the baseline: these students are in a position to take advantage of high returns to education. The most evident consequence of this decline in quality and quantity of college students is in terms of productive efficiency of the economy: output falls by 2 percent permanently.

One notable aspect of the results in panel A of table 8 is the differential effect of the policy change on men and women: in general equilibrium, the drop in female college attainment is about 25 percent larger than that for men. Gender bias in altruism partly accounts for the differences between men and women, as women rely on grants more than men because of the smaller transfers they receive from parents. We also observe that while college attainment falls more for women, the gender wage gap among college graduates marginally widens. This follows from the fact that our estimates of labor shares imply that $s^{m,CL} > s^{f,CL}$ in the production function (eq. [4]). Thus, even though the fall in quality-adjusted female college labor input is larger than for its male counterpart, the positive impact on its marginal product is smaller.

The total ex ante welfare loss in consumption equivalent units is sizable at 2.8 percent. The welfare losses due to a lower average level of consumption and more unequal initial conditions are −2.4 and −1.7 percent, respectively (see online appendix table J.5). As explained, in this economy, average productivity suffers from lower schooling levels and worse sorting of children by ability. Inequality in initial conditions deteriorates for two

[39] Note that we control for changes in the distribution of college student characteristics when calculating parental transfer changes.

reasons. One is that grants provide a substantial source of insurance behind the veil of ignorance against lower than average draws on parental characteristics. The second is the change in relative prices: the rise in the college premium redistributes against low-income low-ability individuals who do not enroll in college.

However, there is an offsetting positive welfare effect (+1.3 percent) due to a reduction in average volatility of consumption in the population. This counteracting force arises because, as seen in table 3, the wage processes of noncollege workers (now more numerous) display less uncertainty than those of college-educated workers.[40] This is particularly evident for the initial variance of the productivity shock, which is the most difficult component to insure because it affects young workers with low savings or in debt.

2. Removing Federal Loans

When federal loans are removed, college attainment drops by 9.5 percentage points in partial equilibrium (see table 8, panel B). This strong response suggests that, in spite of the large crowding in of inter vivos transfers (which increase by $6,000 on average), in the short run many families are unable or unwilling to make up for the elimination of the loans available to college students, and so their children are no longer able to finance education.

In general equilibrium, the overall drop in the college graduation rate is much smaller (3 percentage points) because of the factor price adjustments but also because of the substantial increase in family savings: faced with the harmful removal of a large source of college financing, families devote more resources to saving for college, despite being on average poorer in the new equilibrium (aggregate income falls by 2 percent). Given the large size of the federal loans program, those families who cannot count on private credit (types $q = 1, 2$) are compelled to save much more to send their children to college. Online appendix table J.3 shows that inter vivos transfers in households whose children enroll in college increase by $5,200 for $q = 1$ families and by $10,500 for $q = 2$ families compared with a reduction of $23,000 in borrowing capacity. This behavior represents a crowding in of roughly 24 percent for the wealth-poor and 46 percent for middle-class households relative to the size of the loans program.

There is, again, a significant worsening of selection on ability and on family wealth, which is even more substantial than that occurring after

[40] Table 3 also shows that the persistence of the shocks is higher for college graduates, making self-insurance harder.

removing grants, suggesting that many highly skilled people rely on existing federal loans to finance college. The change in college attainment of children in the bottom tercile of the wealth distribution is large, from 20 percent to less than 8 percent. The welfare losses are slightly larger and, as for the grant removal, are associated with the level and inequality effects (table J.2).

3. Removing Both Federal Grants and Loans

Removing the entire existing structure of financial aid results in qualitative patterns that are similar to what we find after removing either grants or loans. However, cumulative effects are larger. Table J.7 in the online appendix shows that college attainment in the long run drops by 5 percentage points and becomes much less sensitive to ability and much more sensitive to parental wealth. College attendance in the top terciles of cognitive and noncognitive ability drops significantly more than when removing grants or loans alone. Moreover, college attainment among children from the bottom tercile of parental wealth drops precipitously: it falls from 20 percent in the benchmark to less than 1 percent. The poorest parents cannot afford to replace lost financial aid, and children who persist in education even without financial aid are those who received relatively large transfers in the benchmark. To understand how student labor supply and parental transfers react in this experiment, it is important to remember that this new equilibrium selects heavily against college attendance for those from poor families. Thus, for example, average student labor supply actually falls because wealthy students do not need to work in college to finance their studies.

Aggregate output falls by 4.1 percent, and ex ante welfare drops by 5.8 percent. Notably, the average labor income tax increases by 1.9 percentage points: the same amount of expenditures G must be financed through a smaller tax base. Online appendix tables J.7–J.9 document these findings in more detail.

4. The Role of the Intergenerational Transmission of Skills

Reinforcing patterns to these policies emerge through the intergenerational transmission of skills. The child skills depend on the maternal levels of skills and her education. Thus, when grants and loans are removed, the cognitive and noncognitive factors for future generations decline (see online appendix table J.8). Both affect educational attainment, and the cognitive factor also has a direct impact on wages.

To quantify what this decline means, we compute the resulting effect on average wages, using as weights the proportions attending each education level at baseline.[41] We find that when both types of financial aid policies are suppressed, the overall skill loss amounts to a 0.46 percent decline in wages.

This decline is then compounded by the resulting fall in education levels, leading to a reduction in the returns to skills.[42] Thus, the decline in skill is an important channel for the overall reduction in output (and welfare) resulting from eliminating these student aid policies.

Part of the return to investing in college for children is that the grandchildren will tend to have higher abilities (which is internalized by the current generation to an extent driven by the amount of altruism). This is one of the reasons selection into education by parental wealth increases in the long run after financial aid programs are removed.

5. Small Open Economy

Our sensitivity analysis in online appendix K shows that when these same experiments are run under the assumption of a fixed interest rate (i.e., a small open economy), the results are qualitatively similar. However, both welfare and GDP losses are smaller. The reason is that in the closed economy the fall in household saving (and thus of the capital-labor ratio) is reflected in a reduction in average wages. In the small open economy version, this effect is moderated by the fact that capital flows from the rest of the world and keeps domestic wages from falling too much.

B. Expansion of Loans Program: An Upper Bound

Expansions of the federal loan program are potentially valuable if many individuals in the economy are initially constrained in their choice of education. To assess the severity of institutional borrowing limits, we study how allocations and choices would change in an unconstrained economy. Namely, we compute the long-run equilibrium of an economy where there is no ad hoc credit constraint, with the exception of the natural borrowing limit implying that all liabilities must be extinguished upon retirement (e.g., see Hai and Heckman [2017]). All borrowing is done through private markets at the prevailing equilibrium rate r^-. The aim of this exercise is to compute an upper bound for the gains that a federal unsubsidized student loan program can achieve if expanded over and above its current configuration.[43]

[41] More precisely, we calculate a counterfactual average wage in a way that holds the proportion of each ability type attending each education level constant at baseline but varies the proportion of each ability type according to the counterfactual ability distribution.

[42] Remember that the returns to skill are lower for wages corresponding to lower education levels.

[43] To focus on the role of credit, we maintain tuition subsidies at their benchmark values.

Table 9 shows that in the long-run equilibrium of the unconstrained economy, college attainment is about 2 percentage points higher. Sorting on ability improves somewhat, especially for children from poor households who suffer from scarce family resources and low transfers in the benchmark. Conditional on going to college, the financing mix of education changes: private debt replaces parental transfers and earnings from part-time work of college students.

In this unconstrained economy, aggregate output grows by 1.7 percent, a rise attributable to higher levels of education and more efficient sorting into education by ability. Aggregate welfare rises substantially by 4.2 percent. The gain due to level effects is 1.7 percent, welfare improvements due to equalization of initial endowments are worth 1.5 percent of consumption annually, while an improvement in consumption smoothing induces a welfare gain of nearly 1 percent.

These results suggest that there is only a small fraction of children (approximately 2 percent) whose education decisions are affected by credit constraints. However, these children tend to be high ability, and for that reason the long-run impact of credit frictions in the economy is nontrivial. Since our calculation is an upper bound, we conclude that the gains from an expansion of the federal loan program would be rather limited. Detailed results for this experiment are reported in online appendix tables J.10–J.12.

TABLE 9
COUNTERFACTUAL ECONOMY WITH LOOSE PRIVATE CREDIT LIMITS AND WITHOUT ANY FEDERAL STUDENT LOAN PROGRAMS: UNCONSTRAINED ECONOMY

	Benchmark	Partial Equilibrium Long Run
College graduation rates:		
Men	.294	.317
Women	.280	.300
Top one-third of cognitive skills:		
Men	.538	.561
Women	.519	.543
Total:		
Top one-third of parental wealth	.399	.394
Bottom one-third of parental wealth	.205	.238
Other statistics:		
Crowding out of inter vivos transfers ($):		
Male	. . .	−4,987
Female	. . .	−3,771
Student labor supply (%)	. . .	−25.6
Aggregate output (%)	. . .	+1.73
Welfare gain (%)	. . .	+4.23

C. *Expansion of the Grants Program*

Next, we turn our attention to how expansion of the existing federal grants program would affect equilibrium outcomes. We consider three possible ways to expand the current system of tuition subsidies. The first approach is to simply increase by $1,000 per year the amount by which every college graduate's education is subsidized. Any additional net costs from this expansion must be paid for, and we choose to adjust labor income tax rates to this end.

Our second approach strengthens the progressivity of the existing federal grants program by increasing grants proportionally. The result of this means-tested expansion is that poorer ($q = 1$) students benefit the most and richer ($q = 3$) students the least in terms of the absolute amounts of the subsidy. The proportional increase we implement is 53 percent, chosen so that the immediate (partial equilibrium) cost to the government equals that of the general $1,000 per year expansion.

Finally, we implement an ability-tested grant expansion, where increased funding is proportional to cognitive skills. Here grants are increased above their benchmark values according to a linear function of cognitive skills of the form $1.72 \times \theta_{cog}$. This expansion provides a median-ability child with an extra $860 per year in grants and a child in the top tercile with an additional $1,100 per year. Once again, the short-run fiscal costs of this policy reform are the same as in the general grant expansion. Table 10 summarizes the results of these three experiments.

Qualitatively, all three experiments feature the same pattern: the college graduation rate increases in the long run. Sorting on ability rises, and sorting on wealth falls. Overall, the larger and better stock of college graduates produces improvements in equilibrium output and welfare. Grants crowd out inter vivos transfers and student labor supply. For each additional dollar of grants, transfers fall on average by 25–50 cents and student earnings (from their labor supply while in college) by 10 cents. Both of these crowding-out effects mitigate the effect of the policy.

All grant expansions result in welfare gains: +1.4 percent for means tested, +1.7 percent for a general expansion, and +1.9 percent for ability tested. These welfare gains are accompanied by different levels of growth in average skills and output, with the biggest gain (+0.2 percent for skills and +1.2 percent for GDP) associated with the ability-tested grant expansion. This program is better at targeting those with high ability who would otherwise not attend college, hence generating the largest efficiency and welfare gains.

One important source of these gains is that mothers' skills and education interact positively in the production of the next generation's skills. Individuals do not fully internalize the impact of their education decisions

TABLE 10

Three Alternative Expansions of the Federal Tuition Grant Program

	Benchmark	Partial Equilibrium Short Run	General Equilibrium Long Run
	A. General Tuition Grant Expansion		
College graduation rates:			
Men	.294	.335	.311
Women	.280	.318	.296
Top one-third of cognitive skills	.528	.577	.544
Total:			
Top one-third of parental wealth	.399	.416	.405
Bottom one-third of parental wealth	.205	.263	.226
Other statistics:			
Crowding out of inter vivos transfers ($):			
Male	...	−2,694	−1,157
Female	...	−1,989	−778
Student labor supply (%)	...	−4.55	−6.24
Aggregate output (%)	...	...	+1.10
Welfare gain (%)	...	...	+1.72
	B. Means-Tested Grant Expansion (53%)		
College graduation rates:			
Men	.294	.342	.310
Women	.280	.325	.294
Top one-third of cognitive skills	.528	.585	.536
Total:			
Top one-third of parental wealth	.399	.406	.371
Bottom one-third of parental wealth	.205	.288	.248
Other statistics:			
Crowding out of inter vivos transfers ($):			
Male	...	−1,237	−1,358
Female	...	−1,006	−1,061
Student labor supply (%)	...	−4.19	−4.56
Aggregate output (%)	...	...	+.77
Welfare gain (%)	...	...	+1.40
	C. Merit-Based Grant Expansion ($1.72 \times \theta_{cog}$)		
College graduation rates:			
Men	.294	.325	.310
Women	.280	.310	.295
Top one-third of cognitive skills	.528	.566	.550
Total:			
Top one-third of parental wealth	.399	.412	.405
Bottom one-third of parental wealth	.205	.249	.225
Other statistics:			
Crowding out of inter vivos transfers ($):			
Male	...	−1,803	−1,438
Female	...	−1,482	−623

TABLE 10 (*Continued*)

	Benchmark	Partial Equilibrium Short Run	General Equilibrium Long Run
Student labor supply (%)	. . .	−3.39	−6.69
Aggregate output (%)	. . .	. . .	+1.20
Welfare gain (%)	. . .	. . .	+1.89

NOTE.—All expansions are financed through the same short-run budget (identical short-run costs).

on the skills of future generations because of imperfect altruism. The reforms that encourage more high-ability individuals to opt for college, like ability-tested grants, partly correct for this distortion between private returns and intergenerational social returns.[44] Detailed results for these experiments are reported in online appendix tables J.13–J.21.

D. *Optimal Marginal Expansions of Student Aid*

Solving for the optimal public policy is very complex. Here we explore a simpler approach: we consider how best to spend a windfall of 1 percent of residual government expenditure (G) among four specific alternatives: (1) an ability-tested grant expansion, (2) an expansion of the existing means-tested grants program, (3) extending student loans subsidization, and (4) cutting the labor income tax rate.

In the long-run equilibrium, this windfall allows ability-tested grants to increase by the proportional transfer rule $3.6 \times \theta_{cog}$. This amounts to an extra $2,300 per year among the top one-third of the ability distribution. Alternatively, for the means tested case, we can increase grants by 210 percent above their benchmark amounts. For the case of increased loan subsidization, we assume that the government foregoes interests on all loans during college years. Additionally, the small amount of government funds that remain after this change are used to forgive 3 percent of the principal students owe at graduation. We compare these student aid policies with a tax cut, where taxes are reduced by 0.7 percent of aggregate labor income and therefore the marginal tax rate is cut from 0.27 to 0.263.

As seen in table 11, these simulations suggest that ability-tested grants improve welfare the most by better targeting those who are best suited to attend college in terms of ability. Second-best are means-tested grants that also allow some of those with low-wealth parents and high ability to attend. However, this type of grant is not as effective at targeting the right group

[44] See Bovenberg and Jacobs (2005), who explore the role of education subsidies in an optimal taxation framework.

TABLE 11
ALTERNATIVE USES OF WINDFALL EXPENDITURES

	Ability-Tested Expansion[a]	Means-Tested Expansion[b]	Loan Subsidization Expansion[c]	Labor Income Tax Rate Cut[d]
Aggregate output (%)	2.24	1.52	.50	.34
Welfare gain (%)	3.05	2.48	.45	1.30
College (percentage points):				
Overall attainment	2.87	2.75	.78	.29
Top one-third of cognition	4.09	1.24	.04	.34

NOTE.—We compare the outcomes of using a windfall of public funds to expand grants, expand loan subsidization, or cut labor income taxes.

[a] The ability-tested expansion increases grants by a factor equal to $3.6 \times \theta_{cog}$.

[b] The means-tested expansion increases benchmark grants proportionally by 210 percent.

[c] Expansion of loan subsidization expands eligibility to all students and all amounts borrowed and additionally forgives 3.04 percent of the principal owing at graduation.

[d] The tax cut afforded by the available resources is 0.7 percentage points so that the tax rate drops from 27 percent to 26.3 percent.

and distorts prices in such a way that some lower-ability individuals increase attendance too. The next best alternative are tax cuts: they reduce labor market distortions and realign the returns to education closer to the marginal product. However, they are not nearly as effective as expanding grants. Finally, the expansion of subsidized loans is the least effective approach to improving welfare in this economy, in line with the results from our unconstrained economy.

E. *Discussion*

The design of education finance programs is an issue at the top of the policy and research agenda. How valuable is the existing system of tuition grants and student loans? How large are the potential gains from expanding these programs further? To what extent do these policy interventions crowd out the private provision of resources devoted to financing education costs? In this section, we address these key questions.

A clear-cut conclusion of our policy experiments is that the existing student aid program, including grants and subsidized loans, is welfare improving. This welfare gain accrues because our model, carefully crafted to mimic the US economy, features several departures from social efficiency. First, the private cost of education exceeds the social one because of liquidity constraints that, in particular, prevent some high-ability students from enrolling in college. Federal aid realigns private and social cost. Our quantitative analysis, however, shows that this market failure is not especially significant. Second, the private return to education is below its social counterpart for three reasons: (1) uninsurable income uncertainty makes education a risky investment, (2) distortionary progressive taxation reduces the gain from investing, and (3) imperfect parental altruism means that individuals do not fully internalize that as educated parents they raise children with better skills. Tuition grants increase the private financial return to college, thus shrinking the gap with social returns. Finally, market incompleteness is a source of pecuniary externalities. By increasing the quantity and quality of college graduates, these policies reduce the college premium and redistribute toward the more needy households. Key for this channel is the imperfect substitutability of men and women and of workers of three different education levels in production, a feature emphasized before us by Heckman et al. (1998b, 1998c), Lee (2005), Lee and Wolpin (2006), and Johnson and Keane (2013), for example.

Another important result of our policy counterfactuals is that there is room for an expansion of federal aid, but this room varies substantially across types of intervention. We find that a windfall government expenditure is best spent expanding grants for college students rather than on increasing loan limits. The reason is that, as explained above, liquidity constraints are not widely binding for the marginal population, whereas grants are effective at increasing the return to college. Among grants, those targeted to high-ability children are superior to simply means-tested ones because they are better at inducing into college those children for whom the gains are largest.

In line with this discussion, our welfare decomposition identifies two main sources of welfare changes from policy reforms that increase college attainment and improve sorting by making attendance depend more on skills and less on parental wealth: (1) improvements in aggregate output due to a higher stock of human capital and (2) reduced inequality in initial conditions due to a redistribution of income occurring through a shrinking relative price of college-educated labor.

Finally, we have highlighted two key margins of adjustment that are not typically considered in the traditional policy evaluation literature. The first channel is the adjustment of funding by parents through inter vivos transfers, which is a sizable source of support during college in the data. The second channel is students' labor supply. Our experiments show that both margins are quite elastic with respect to policy interventions and, as such, mitigate their effects. We find that an additional dollar in grants provided by the government crowds out on average 35 cents of private parental transfers in the long-run equilibrium. There is, however, substantial heterogeneity in crowding-out effects. More generous grants displace transfers in different proportions depending on family resources, with the transfers made by wealthy families being generally crowded out the most. Also, student labor supply is sensitive to policy. Across experiments, an extra dollar in grants crowds out 10 cents in labor earnings by students in college. Accounting for the existing patchwork of policies, adjustments in these alternative means of privately funding education replace/displace around 45 cents of every dollar subtracted/added to federal grants. This result suggests that policy evaluations that omit these joint adjustment margins might be misleading.

Our model is rich and realistic in many dimensions. At the same time, its computational complexity forced us to abstract from a number of additional aspects that might influence policy evaluation.

We modeled the endogeneity of the distribution of abilities by assuming that a child's ability depends on parental education and skills in a mechanical way. A parallel line of research (e.g., Cunha and Heckman 2007; Cunha et al. 2010; Caucutt and Lochner 2012; Heckman and Mosso 2014) stresses the importance of complementarities between college-age policies and interventions during critical phases of child development. Explicitly modeling sequential human capital investments at different stages of a child's life would flesh out the extent to which early interventions may improve the effectiveness of tertiary education policies and how this affects intergenerational transmission.

Another interesting generalization would account for heterogeneity in college types (e.g., Fu 2014) allowing for the endogenous determination of returns based on demand and supply of different college types, thereby recognizing that more able and richer students are, in equilibrium, matched with better colleges. This complementarity may strengthen the role of financial aid policies that improve sorting. Similarly, the role that choice of college major has is an important but relatively underresearched area (see, e.g., Altonji, Blom, and Meghir 2012).

Recent work (see Lochner and Monje-Naranjo 2011; Ionescu and Simpson 2016) has emphasized the expansion of private provision of student credit. Nesting endogenous borrowing constraints within an equilibrium framework, similar to the one developed in this paper, would allow for explicit codetermination of all credit and skill prices. Such a model, while significantly more complex, could answer interesting questions about how the price of borrowing in private markets would endogenously respond to education policy reforms.

In all our counterfactual policy experiments, we kept the configuration of all other fiscal policies unchanged, although we did compare the relative merits of expanding student aid to reducing taxes on labor. As emphasized by Krueger and Ludwig (2016), there is a certain degree of substitutability between progressive taxation and education subsidies: both policies induce some redistribution, the former through fiscal instruments and the latter through relative prices of different types of labor. An implication of this observation to bear in mind when interpreting our findings is therefore that they are conditional on the prevailing degree of progressivity of the tax/transfer system, but major tax reforms could significantly affect the landscape of effective education policies. However, locally, we show that student aid is more effective at improving overall welfare than tax cuts.

Finally, an important issue we do not consider here are transitional effects. Many of these policies may have upfront costs for longer-term benefits to future generations as we move from one steady state to another. As Krueger and Ludwig (2016) show, the costs during the transition may change our view about the merits of policy and certainly raise the issue of how a policy should be introduced and financed. For example, long-term government debt, with the costs falling on future generations, may be a better way of financing the transition instead of taxes falling on the current ones. However, our model has little to say about these issues, and this would have to be left to future research.

VI. Conclusions

The capacity of people to optimally invest in education is crucial for economic prosperity and social mobility and is an important determinant of income distribution (see Becker and Tomes [1979] and Loury [1981]). In the presence of insurance and credit market imperfections that prevent those individuals with the highest returns to education from investing in schooling, education policies can improve allocations and welfare.

In this paper, we have assessed the role played by the existing system of government financial aid to college. For this purpose, we have specified and estimated a general equilibrium life cycle model of the US economy that features (1) intergenerational linkages through altruism and paternalism that determine the extent to which parent are willing to finance their children education; (2) intergenerational transmission of abilities that is affected by parental education and is consequently endogenous; (3) nonpecuniary psychic costs of education that depend on cognitive and noncognitive abilities; (4) liquidity constraints that limit access to credit; (5) idiosyncratic uninsurable earnings risk that makes education an investment with an uncertain outcome; (6) various means of financing the pecuniary cost of education over and above what is offered by the government, such as parental transfers, private borrowing, and labor supply in college; and (7) imperfect substitution between gender and education groups in production, which leads to redistributive implications of education policies through relative prices.

We use microeconomic data from various sources to estimate the structural parameters of the model. The model fits the data well, including responses to actual policies that we do not target in the estimation. It also provides valuable insights on the intergenerational transmission of income and education.

Through the lenses of our model, our bottom line is that the current configuration of federal loans and grant programs has substantial value in terms of both output and welfare. Our results indicate that further expansions of grant programs would be welfare improving. Among the alternative policies we consider, the best way of expanding student aid is via ability-tested grants. Part of the efficacy of this form of grants is that parental ability and education interact positively in the production of skills of the next generation.

Appendix

Here we report externally specified parameter values and estimates from our main estimation exercise. We also compare fitted and data values for our targeted moments.

TABLE A1
Externally Set Parameters

Parameter	Value	Description
Demographics:		
ζ_j	Varies	Mortality rates for retired household based on US Life Tables 2000
Preferences:		
γ	1.5	Determines intertemporal elasticity of substitution (.5)
ν_j^m	5.5	Determines average Frisch elasticity of labor supply for men and nonmothers (.33)
ν_{30-45}^f	5.7	Determines average Frisch elasticity of labor supply for mothers (.67)
$\tilde{\rho}$	1.4	Economies of scale parameter (Voena 2015)
$\bar{t}$	.25	Requires students to study for 25% of time endowment
Technology:		
α	.33	Capital share of GDP
δ	.06	Depreciation rate of capital
Tax and pension system:		
τ_w	.27	Labor income tax rate
τ_c	.05	Consumption tax rate
τ_k	.40	Capital income tax rate
$p(e)$	6.63, 9.86, 19.77	Pension for less than high school, high school, and college, respectively ($6,198, $10,845, $21,744)
Financial market:		
$\underline{a}^{CL}$	77.27	Limits borrowing of college households to $85,000
$\underline{a}^{HS}$	22.73	Limits borrowing of high school households to $25,000
$\underline{a}^{LH}$	13.64	Limits borrowing of less than high school households to $15,000
College loans and grants:		
$\phi(q)$	7.30, 9.26, 9.74	Net tuition fees for $q = 1, 2, 3$ students
ι^u	.063	Interest premium on unsubsidized Stafford loans
$\underline{b}^s$	15.68	Limits subsidized loans to $17,250 for $q = 1$ students
$\underline{b}$	20.91	Limits total student loans to $23,000 for $q = 1$ and $q = 2$ students

TABLE A1 (*Continued*)

Parameter	Value	Description
$\underline{a}^p$	20.91	Limits private loans to \$23,000 for $q = 3$ students
$\underline{w}^{\{q=1\}}$	77.27	Full-time equivalent parental income threshold (\$85,000) for $q = 1$ status

Note.—All sources are listed in the text. Other externally set parameters (whose estimations are discussed in online apps. B, C, and D) are parameters of production function, income processes, and transition matrices for cognitive and noncognitive skills.

TABLE A2
Estimated Parameters

Parameter	Value	Standard Error
	A. Parameters Internally Estimated by Method of Moments	
Time discount factor (β)	.9753	.0413
Male and nonmother female leisure preference (ϑ_j^g)	.0415	.0053
Mother leisure preference (ϑ_{30-45}^f)	.0857	.0049
Redistributive transfer (ψ; \$1,000s)	5.31	.1647
Borrowing wedge that applies to all debt (ι)	.1325	.0355
Interest premium for private student loans (ι^p)	.0590	.0141
Wealth threshold for subsidized government loans ($\underline{a}^{\{q=1\}}$; $q = 1$; \$1,000s)	123.6	4.272
Wealth threshold for unsubsidized government loans ($\underline{a}^{\{q=2\}}$; $q = 2$; \$1,000s)	168.1	4.933
Altruism toward daughters (ω^f)	.4699	.0760
Altruism toward sons (ω^m)	.5178	.1068
Paternalistic utility gain from child graduating from college (ξ)	.2833	.0379
	B. Moments Matched	
	Data Value	Model Value
Annualized capital-output ratio	3.5	3.478
Average male labor supply	.350	.349
Average labor supply of mothers	.220	.219
Var(log disposable income)/var(log gross income)	.610	.609
Fraction of workers with negative net worth	.068	.072
Fraction of students who take out private loans	.134	.164
Fraction of students who take out subsidized loans	.419	.424
Fraction of students graduating with any government loans	.621	.651
Average inter vivos transfers to female child (\$1,000s)	29.09	28.95
Average inter vivos transfers to male child (\$1,000s)	33.16	33.04
Fraction of less than high school female population (cross section)	.136	.136
Fraction of less than high school male population (cross section)	.139	.139
Fraction of college female population (cross section)	.280	.280
Fraction of college male population (cross section)	.294	.294

TABLE A3
Attainment Rates: NLSY97 Data

	Parental Wealth Quartile			
	1	2	3	4
High school dropouts by parental wealth quartile	.2221	.1643	.1146	.0472
High school dropouts by income quartile	.2372	.1623	.0834	.0671
College graduates by parental wealth quartile	.1631	.2011	.3067	.4771
College graduates by parental income quartile	.1413	.2210	.3269	.4588

TABLE A4
Attainment Rates: Model Simulations

	Parental Wealth Quartile			
	1	2	3	4
High school dropouts by parental wealth quartile	.2169	.1515	.0903	.0916
High school dropouts by income quartile	.2252	.1476	.0989	.0795
College graduates by parental wealth quartile	.2003	.2166	.2968	.4344
College graduates by parental income quartile	.1932	.2038	.2534	.4977

TABLE A5
Attainment Rates: NLSY97 Data

	Cognitive Tercile		
Noncognitive Tercile	1	2	3
	A. Skill Distribution of High School Dropouts		
1	.4126	.0800	.0061
2	.2634	.0380	.0000
3	.1618	.0354	.0026
	B. Skill Distribution of College Graduates		
1	.0129	.0607	.1977
2	.0189	.0804	.2339
3	.0371	.1020	.2563

TABLE A6
Attainment Rates: Model Simulations

	Cognitive Tercile		
Noncognitive Tercile	1	2	3
	A. Skill Distribution of High School Dropouts		
1	.4149	.0890	.0080
2	.2662	.0343	.0024
3	.1721	.0125	.0007
	B. Skill Distribution of College Graduates		
1	.0136	.0707	.1854
2	.0201	.0918	.2206
3	.0337	.1125	.2517

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