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A DYNAMIC ASSESSMENT

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ABSTRACT

Universal basic income (UBI) is an increasingly popular policy proposal but there is no evidence regarding its longer-term consequences. We study UBI in a general equilibrium model with imperfect capital markets, labor market shocks, and intergenerational linkages via skill formation and transfers. We find that UBI increases-welfare for older agents but has large-welfare losses for younger agents and future generations. A sizable share of the negative effects stem from the endogenous intergenerational linkages. Modeling automation as an increased probability of an "out-of-work" shock, the model provides insights on the changing welfare consequence of UBI in a riskier environment.

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1 Introduction

The idea of universal basic income (UBI) — a set income that is given to all without any conditions — is making an important comeback in many countries. This is most likely the result of anxieties about automation and robotization, the depth of the last recession both in the US and in Europe, the stagnation of median wages over several decades in an era of rising inequality and, very recently, the large-scale increase in unemployment in response to the coronavirus epidemic.[1] What do we know about UBIs? What problems would an UBI ameliorate and which would it aggravate? These are important questions whose answers depend on the features of the economy under consideration and the generosity of the UBI grant.[2]

There is no real experience in advanced economies with a UBI policy, although studies have made use of variation in income arising from changes in oil revenue or EITC generosity to study potential consequences.[3] Although much of the attention has been on the effects of programs on labor supply, it may very well be that the more important consequences of a UBI are intergenerational.[4] There have not been, however, long-run large-scale experiments that allow one to evaluate the longer-term intergenerational consequences of these programs nor their implications at an economy-wide level, i.e., in general equilibrium. As stated by Hoynes and Rothstein (2019) in their excellent review article on UBI in advanced economies, "we have a good deal of evidence from a range of settings that substitution effects on short-run labor supply are moderate and income effects are small. There is also clear evidence that additional family resources improve children's outcomes, including health and school achievement. The major open questions about UBIs, in our view, relate to longer-run effects, which are much harder to study using randomized and natural experiments."

In this paper we provide a very inexpensive evaluation of such a program by studying its consequences in a computational model laboratory. We develop a model that incorporates many of the most important channels that affect the costs and benefits associated with a UBI policy. The model features an economy with imperfect capital markets and overlapping generations. An individual's first decision is an education choice (college) based on their assets, skills, and their taste for education. Skills themselves are endogenous: the result of investments of time and money made by parents during an individual's early childhood. College can be financed with a combination of parental transfers (which are endogenous),

[1]A UBI policy has been advocated by people ranging from Pope Francis, to Elon Musk, or to former US presidential candidate Andrew Yang as well as by senior officials in organizations such as the United Nations or the World Economic Forum (see Wignaraja (2020)).

[2]See Gentilini et al. (2019) for a recent excellent review of UBI history and lessons from diverse country experiences.

[3]The Alaska Permanent Fund and the Eastern Cherokee Native American tribe are programs which provide demogrants to adults. The first makes payments which may vary from year to year, ranging from \$1000-2000 per person per year and financed by Alaska's oil revenues. The second provides payments of around \$4000 per person per year financed out of tribal casino revenues. See Jones and Marinescu (2018) and Akee et al. (2010, 2018).

[4]For example, policies that increased maternal employment and family income (Morris et al., 2009) were found to increase child achievement. Programs such as SNAP and the EITC improve health at birth (e.g., Almond et al., 2011) and increased generosity in the EITC is also associated with higher children's achievement (Dahl and Lochner, 2012; Chetty et al., 2011) and educational attainment (Bastian and Michelmore, 2018; Manoli and Turner, 2018).

working while in college, and borrowing. After education, an individual works, has children, makes time, money, and transfer decisions towards their child, and eventually retires and dies. These intergenerational linkages are embedded in a fairly standard general equilibrium life-cycle Aiyagari framework with wage uncertainty, including a more novel "out-of-work" shock, and with a tax function calibrated to the US economy. This framework allows aggregate education, skills, and savings to affect prices and the endogeneity of these outcomes means that they are affected by the additional income provided by UBI and via the change in taxes required to finance this policy.

The steady state of the model is parameterized and estimated to match household-level data using a variety of data sources such as the Panel Study of Income Dynamics (PSID), the Child Development Supplement (CDS) to the PSID, and the 1979 cohort of the National Longitudinal Survey of Youth (NLSY79). We validate the model in a variety of ways, must notably by conducting the appropriate partial equilibrium exercises in the model to compare its predictions with those on child development and cash transfers (Dahl and Lochner, 2012) as well as estimates of the elasticity of labor supply (Blundell and MaCurdy, 1999) .

We introduce the UBI policy as a lump-sum transfer made annually to all individuals once they reach adulthood. What are the benefits of a UBI policy? In an economy in which individuals are subject to both wage and employment shocks and in which credit and insurance markets are imperfect, UBI allows for greater smoothing of consumption and the guarantee of a minimum standard of living. It can also allow agents to undertake relatively expensive investments — in our model, attend college — at a lower cost than via borrowing. Furthermore, it can have beneficial intergenerational consequences by facilitating parental investment in their child's skill formation.[5] Of course, any positive effects of UBI must be weighed against the cost of increased distortionary taxation in order to assess the net welfare impact.

We find that a UBI policy that unconditionally gives all households a yearly income equivalent to the poverty line level ($11,000 per household per year as measured in year 2000 dollars) has different implications for generations that are alive when the policy is introduced relative to future generations.[6] The policy is generally welcomed by poorer households — those hit by out-of-work shocks as well as those with low skills or without a college education. It is, however, a very expensive policy to implement. The higher tax rate required to finance this policy reduces investment in skills, lowers the share of agents with college education, and decreases saving, requiring even higher taxes over time. This leads younger agents and all future generations, operating behind the veil of ignorance, to prefer to live in a world without UBI – they are willing to sacrifice up to 9% of consumption to do so. In aggregate terms, we find that the UBI policy is associated with a long-run GDP reduction of 12.9%, explained in almost equal parts by reductions in capital and efficiency units of labor.

[5]The literature on UBI has also pointed to other, mainly psychological and mental health benefits, which we do not assess here but are important to consider as well in a fuller evaluation of this policy. There are also important ethical and philosophical arguments made on its behalf (Van Parijs and Vanderborght, 2017). See also Ghatak and Maniquet (2019) for a theoretical assessment of the desirability of a UBI.

[6]The poverty threshold for a 2-adult household, as defined by the U.S. Census, was $11,235 in the year 2000.

To evaluate a reasonable alternative scenario in which UBI replaces some current spending on poorer individuals, we also consider a variant in which UBI allows the current progressive tax rate to be replaced by a linear tax schedule. We find similar results regarding winners and losers as with the original UBI policy. We also ask how results would be modified if consumption taxes were used instead. In this case, the results are quite different: cohorts who are adults when the policy is introduced lose whereas future generations gain substantially. The gain, however, is not due to UBI but rather can be shown to stem from a greater reliance on consumption taxation relative to labor taxes.

We investigate the main channels responsible for the conflicting cohort preferences over the desirability of UBI. We can use the OLG structure to study adjacent cohorts that differ only in whether UBI was introduced before versus after their parents had invested in their skill formation. Similarly we can compare cohorts that differ only in whether their parents had already transferred funds to them prior to the introduction of UBI. These exercises allow us to show that intergenerational linkages play a quantitatively important role in explaining preference differences across cohorts over the transition to the new steady state. A further exercise highlights the importance of intergenerational links for the welfare loss suffered in the new steady state. By keeping the value functions at their benchmark-economy steady-state values but changing the distribution of agents over the (parental determined) state space to mimic the ones in the UBI steady state, we can show that over 40% of the steady-state welfare loss is due to endogenous parental responses to the UBI policy.

The model is also able to provide insight on how a riskier economy might affect the desirability of UBI. Using estimates provided by the literature on the possible job loss that might arise from increased automation/robotization, we incorporate the latter as a higher probability of being hit by an "out-of-work" shock, modifying the aggregate production function as well to reflect the increased importance of college labor and higher TFP. We find that greater "automation" increases the polarization of preferences regarding UBI between current adults vs. future cohorts. Our results suggest that while UBI may be a useful transitional policy to help current individuals whose skills are more likely to become obsolete and may have not prepared for the increased risk, its longer-run effects remain negative in an economy with increased risk.

Some Related Literature

Although notable economists such as Tony Atkinson used public finance tools to evaluate UBI polices several decades ago (see, e.g. Atkinson (1991)), there are few studies of actual UBI policies. This is undoubtedly a consequence of the absence of programs that fulfill the criteria of being universal and significant in size. In a developed country context, the Earned Income Tax Credit (EITC), the 1970s Income Maintenance Experiments, cash welfare programs, and programs such as the Alaska Permanent Fund and the Indian tribe payments can be used to study some of the potential behavioral responses to a UBI. For excellent reviews of the literature see Gentilini et al. (2019) overall, Hoynes and Rothstein (2019) for high-income countries and Banerjee et al. (2019) and Hanna and Olken (2018) for developing countries.

Our paper is the among the first to study the welfare consequences of a UBI policy in a dynamic, general equilibrium, quantitative framework. Earlier work by Lopez-Daneri (2016) examined a negative income tax reform as suggested by Milton Friedman. This is a particular version of UBI (similar to the one we study under the linear labor-income taxation variant of the UBI policy). Lopez-Daneri (2016) finds significant behind-the-veil-of-ignorance welfare gains for agents born after the policy is introduced. These results are quite different from ours and this is likely due to critical differences in modeling strategies. Lopez-Daneri (2016) studies an open economy (i.e., one with a fixed interest rate) with no human capital accumulation and no intergenerational linkages. Our paper shows that all three factors play an important quantitative role for our welfare results.

Another related paper is Fabre et al. (2014) which compares UBI to unemployment insurance. This paper abstracts from any general equilibrium and intergenerational considerations. Its focus is on whether an unconditional program such as UBI can dominate a conditional program such as unemployment insurance given that the former does not require monitoring whereas the latter does. Interestingly, the authors find that the additional tax burden imposed by UBI outweighs its no-monitoring advantages for all but implausibly high costs of monitoring.

In a paper contemporaneous to ours, Luduvice (2019) also studies the effects of a UBI policy in a quantitative general-equilibrium model. Our models share several features: an OLG structure with idiosyncratic labor income shocks and with outcomes determined in general equilibrium. They also differ in some important respects. Luduvice (2019) has a slightly richer demographic structure (with stochastic death and households both with and without children) and incorporates more explicit features of the income security system (with specific cut-offs regarding income and wealth). Parents, however, do not care about their children and there are no skill or education outcomes. Although Luduvice (2019) studies a UBI policy of a similar magnitude to the one in this paper, he finds that welfare increases in the long run – a very different conclusion from ours. This may be a function of the degree of distortion that he imposes on the benchmark economy (in which both both saving and work are faced with important kinks in their tax schedules) and from using consumption taxes to finance the policy (which tends to increase long-run welfare–a result we have in common). Moreover, as in Fabre et al. (2014) and Lopez-Daneri (2016), intergenerational linkages are absent. In our model, on the other hand, parents and children are linked both because parental education and skills help determine those of their children, but also endogenously because parents are altruistic – they care about their descendants' welfare – and invest in their child's skill formation and transfer funds to them. We show that these are quantitatively significant in determining why the welfare effects of UBI differ in the short versus long-run.

Our paper also relates to the large literature that studies tax progressivity. A particularly relevant recent example is Heathcote et al. (2017), which studies the optimal degree of progressivity of the tax and transfer system in a perpetual youth economy. Their simplifying assumptions (e.g., no capital, fully reversible skill investment choices) allow them to elegantly characterize the economy using closed form solutions. Our more complex economy, on the other hand, requires a computational approach but allows us to study a richer household structure, more complex transition paths, and capital accumulation. In addition, the popular tax and transfer function they study (à la Feldstein (1969), Persson (1983) and Benabou (2000)) rules out policies such as UBI as the functional form imposes strictly zero transfers for those who have no earnings. We extend this tax function, keeping the progressivity estimates from Heathcote et al. (2017) for those with positive labor income, but also allowing for lump-sum transfers.[7]

More generally, our paper is related to a growing literature on the dynamic consequences of tax and education policy. In this literature, Benabou (2002) is a seminal paper that provided closed-form solutions and a welfare analysis for a calibrated model with human, but not physical, capital accumulation.[8] More recently, Krueger and Ludwig (2016) study the optimal labor tax and college subsidy policy in a heterogeneous agent economy with capital accumulation. In their model, agents' borrowing is restricted to college loans. They find that the optimal college subsidy is large, and even larger in a general equilibrium than in partial equilibrium as subsidizing college decreases the skill premium, redistributing income across education groups. The current labor tax rate, however, needs to be reduced in order not to impose large costs in the transition to the steady state. Our paper does not characterize the optimal policy but instead examines the welfare implications of a popular policy proposal. In the model, we allow agents a greater degree of ability to self-insure and smooth consumption by permitting them access to limited borrowing. Furthermore, the endogenous links between parents and children allow policies that redistribute income such as a UBI to play an additional role through potentially higher parental investments in a child's human capital.

A key feature of our model is the endogenous link between parents and children within a macroeconomic framework. This link is also found in Daruich (2019) and Lee and Seshadri (2019), both of which also allow parental investments in the form of money and time to affect the child's human capital. Lee and Seshadri (2019) use their model to quantify the importance of parental background on intergenerational mobility and Daruich (2019) uses his to study the effects of introducing an early childhood development program.

Lastly, our model allows allows agents to be hit by very bad shocks that absent them from the labor force for a substantial amount of time, as in the data. This outcome allows us to study economies characterized by different degrees of job loss due, potentially, to automation/robotization. We see this simple extension as a complement to the richer task-based approach in recent quantitative models (see, e.g., Humlum (2020) and Martinez (2019) for recent contributions and a review of this literature). By appropriately increasing the probability of extended unemployment from greater risk of skill/occupation obsolescence, we are able to use our estimated model to evaluate a UBI policy in the context of increased automation.

The paper is organized as follows. Section 2 introduces the model, and Section 3 explains its estimation

[7] Boar and Midrigan (2020) also use this modification to the tax function as it fits the data better.
[8] See also Bovenberg and Jacobs (2005).

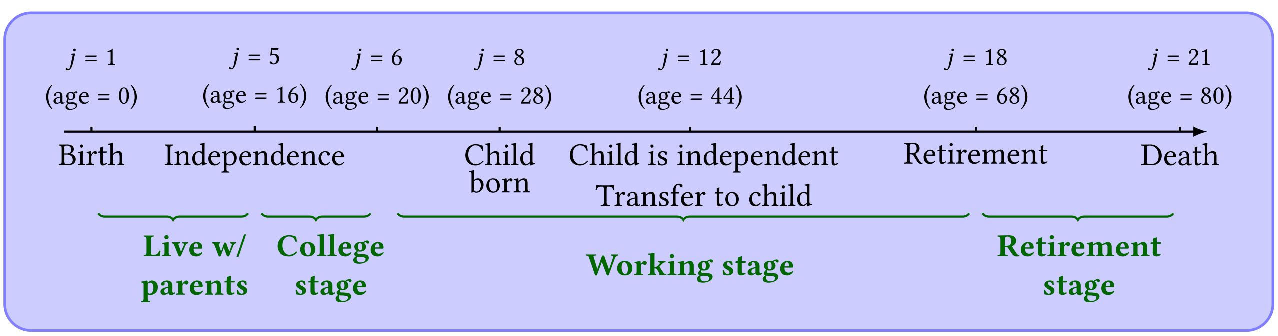
and conducts several validation exercises. Section 4 presents the model's results regarding UBI using various tax schemes and explores the main channels behind the main welfare results along with some robustness checks. Section 5 evaluates the UBI policy under different levels of riskiness (out-of-work shocks). Section 6 concludes. The Appendices contain additional supporting work and results.

2 The Model

This section describes the model in detail. We model the economy with an OLG structure in which agents are endowed with a unit of time and make consumption, savings, borrowing, labor, and education decisions. They endogenously invest in their child's skills and can provide them with a monetary transfer before the child makes their education (college) decision and becomes an adult. The government taxes and provides transfers. Prior to estimating the stationary equilibrium of this economy in the next section, we conclude with a discussion of the potential role of a UBI policy.

2.1 The Environment

Figure 1: Life Cycle



The life cycle Agents live through 20 periods which belong to four main stages: childhood, college, work/parenthood, and retirement. Figure 1 shows the life cycle of an agent, in which each period refers to four years. Let j denote the period of their life (e.g., $j = 1$ refers to ages 0–3, $j = 2$ to ages 4–7, etc.). From $j = 1$ through $j = 4$ (ages 0–15) the child lives with her parents and makes no decisions. In period $j = 5$, the child has finished high school with an (endogenous) level of skills and has received (at the beginning of that period) a non-negative transfer from their parent which becomes their initial assets, a. The agent also learns their school taste (described in greater detail later) and is now considered an adult. The agent now makes their first decision: whether to attend college or to instead enter the work stage of life as a high-school graduate. If the agent attends college, they enter the work stage of life one period later, $j = 6$. In the work stage, agents decide in each period how much to work, save, and consume. They can borrow up to a limit, and save through a risk-free, non-state-contingent asset. While in their work stage, in period $j = 8$ (age 28), the individual becomes a parent (one child), whereupon new decisions — how much time and money to invest in her child — must also be made. An individual retires in period $j = 18$ (age 68) and lives through period $j = 20$ (ages 76-79). Agents die right before the start of period $j = 21$. There is no population growth.

The credit market We assume that agents can only trade risk-free bonds, but allow the interest rate to differ according to whether they are saving or borrowing. Loans used to pay for college have a lower interest rate.[9] Agents with positive savings receive an interest rate r, whereas those who borrow pay an interest rate $r^b = r + \iota$, where $\iota \geq 0$. The wedge between the two interest rates captures the cost of borrowing.[10] In addition, agents face borrowing limits that vary over the life-cycle and by education. To anticipate, we will use estimates of these from the Survey of Consumer Finances based on self-reported limits on unsecured credit.

Progressive taxation and Universal Basic Income To evaluate a UBI policy, it is important to understand how it modifies the progressivity of the existing tax system. The tax and transfer function is given by:

$$T(y, a, c) = y - \lambda y^{1-\tau_y} + \tau_a a r \mathbf{1}_{a \geq 0} + \tau_c c - \omega \tag{1}$$

where y is pre-tax labor income, ar is the interest income earned on (non-negative) assets a, c is consumption, and ω is a lump-sum transfer. We assume that consumption and capital income are taxed by constant tax rates τ_c and τ_k, respectively.[11] As indicated, the relationship between after-tax labor income $\tilde{y}$ and pre-tax labor income y is given by:

$$\tilde{y} = \lambda y^{1-\tau_y} + \omega \tag{2}$$

Note that this is the same non-linear tax function used by, e.g., Feldstein (1969), Benabou (2000), and Heathcote et al. (2017), but augmented to include lump-sum transfers ω. As shown in Heathcote et al. (2017), the tax function of equation 2 with $\omega = 0$, fits the relationship between after-tax and pre-tax income very well for all income quantiles except those at the bottom of the income distribution. Lump-sum transfers ω help match the after-tax income of the poorest individuals and thus enrich the welfare analysis. A UBI can be thought of as an increase in ω. Note that τ_y helps determine the progressivity of the marginal tax rate whereas changes in λ affect after-tax labor income by the same proportion for all.[12]

[9]Student loans are explained in detail below.

[10]As is standard in the literature (e.g., Abbott et al., Forthcoming), these costs are interpreted as the bank's cost of overseeing the loan per unit of consumption intermediated; these are "red tape" costs and do not constitute payments to any agent in the model.

[11]We discuss the parametrization and calibration of the tax and transfer function in Section 3.

[12]As discussed in the estimation section, we use the estimate of τ_y from Heathcote et al. (2017), which takes into account deductions and public cash transfers.

Wage process Individual wages depend on an individual's education e and on their (endogenous) endowment of efficiency units per unit of time worked, E, in the following fashion:

$$w^e E_j^e (\theta, \eta) \tag{3}$$

where w^e is the unit wage of education group e. $E_j^e (\theta, \eta)$ is given by:

$$E_{ij}^e = \epsilon_j^e \psi_{ij}^e \tag{4}$$

where ϵ_j^e is the age profile for the education group e and ψ_{ij}^e is the idiosyncratic labor productivity shock. The latter evolves stochastically following $\Gamma_{e,j} (\eta)$ which can depend on education and age. The parametrization and estimation details are presented in Section 3. We highlight now, however, that the process allows for shocks η such that the wage of the individual (and hence their labor income) is zero, which we interpret as unemployment or disability shocks (and later automation redundancy shocks). This feature is important when studying UBI since one of its potential benefits is that it helps smooth consumption.

The production function We assume there is a representative firm with production technology:

$$Y = AK^{\alpha} H^{1-\alpha} \tag{5}$$

where A is TFP, K is aggregate physical capital and H is a CES aggregator of the labor supply of the two education groups (high school H_0 and college H_1), i.e,

$$H = \left[sH_0^{\Omega} + (1-s) H_1^{\Omega} \right]^{1/\Omega} \tag{6}$$

where H_0 integrates over all the efficiency units per unit of time worked times hours of labor supplied by high-school workers of age j and then sums over all the working ages and H_1 performs the same calculation for college-graduate workers.[13]

We assume that firms are perfectly competitive thus making zero profits and paying unit wages equal

[13]More precisely, let $s_j \in S_j$ and $\mu = \{\mu_j\}$ be the age-specific state vector of an individual of age j and the Borel sigma-algebras defined over those state spaces, respectively (where we have suppressed everywhere the t subscript indicating that these are the distributions at time t). Then H_0 is given by

$$H_0 = \sum_{j=5}^{17} \int_{S_j} E_{j,0} (\theta, \eta) \, h_j \left(s_j | e = 0 \right) d\mu_j + \sum_{j=5}^{5} \int_{S_j} E_{j,1} (\theta) \, h_j \left(s_j | e = 1 \right) d\mu_j$$

where the first summation is the supply of high-school graduates while the second is that labor supply of college students. And, similarly, H_1 is

$$H_1 = \sum_{j=6}^{17} \int_{S_j} E_{j,1} (\theta, \eta) \, h_j \left(s_j | e = 1 \right) d\mu_j.$$

to the marginal product of labor, by education:

$$w_0 = A(1-\alpha)s\left(\frac{K}{H}\right)^{\alpha}\left(\frac{H}{H_0}\right)^{1-\Omega} \tag{7}$$

$$w_1 = A(1-\alpha)\,(1-s)\left(\frac{K}{H}\right)^{\alpha}\left(\frac{H}{H_1}\right)^{1-\Omega} \tag{8}$$

Capital is assumed to depreciate at a fixed rate δ_k per period, thus:

$$r = A\alpha\left(\frac{H}{K}\right)^{1-\alpha} - \delta_k \tag{9}$$

Preferences The agent is risk averse and her period utility over consumption c and labor h is given by

$$u(c,h) = \frac{c^{1-\gamma_c}}{1-\gamma_c} - \mu\frac{h^{1+\gamma_h}}{1+\gamma_h} \tag{10}$$

Furthermore, the future is discounted by β and the parent is altruistic as in Barro and Becker (1989), caring about the utility of the child (i.e, rather than obtaining a "warm glow") as detailed in the next section.

2.2 The Agent's Maximization Problem and Equilibrium

The Education Stage At $j = 5$ (16 years old), the agent faces their first decision: whether to attend college that period. The agent's state variables at the decision point are: initial assets consisting of the (non-negative) parental transfer (which would have been made at the start of that period), skills θ (a vector consisting of a cognitive and non-cognitive skill component), and shock ε (also revealed at the beginning of that period) to the taste for college κ. The latter, as is common in the literature (e.g., Heckman et al., 2006; Abbott et al., Forthcoming), affects the desire for a college education in the form of a psychic cost that enters in a linearly separable fashion.[14] After college, κ no longer affects outcomes. The alternative to spending period $j = 5$ in college ($e = 1$), is to enter the work phase of life as of that period as a high-school graduate ($e = 0$). The education decision is irreversible and college entails a monetary cost p_e.

Agents can finance their college education using a variety of methods: they can use their assets, take out loans, and work. College students can access subsidized loans at rate $r^s = r + \iota^s$ where $\iota^s < \iota$. These loans are subject to a borrowing limit $\underline{a}^s$. Both the interest rate wedge and the borrowing limit are based on the rules for federal college loans, explained in detail in Section 3. To simplify computation, we follow Abbott et al. (Forthcoming) and assume that college student debt is refinanced into a single bond that

[14]Including a taste for schooling is important to match the observed cross-sectional variation in education (e.g., its intergenerational persistence) as variation in income and in the returns to education can only partially account for it.

carries interest rate r^b, where $\tilde{a}^s(a')$ is the function performing this transformation. The transformation assumes that fixed payments would have been made for 5 periods (i.e., 20 years) following graduation.[15]

While in college, students can work — providing high-school level labor — but their total available hours are reduced by a fixed amount of study time $\overline{h}$.[16] Thus, the value function of an agent who decides to attend college and has assets a and skills θ is given by:

$$V_j^s(a,\theta,e=1) = \max_{c,a',h} u\left(c, h+\overline{h}\right) + \beta\mathbb{E}_{\eta'|e=1} V_{j+1}\left(\tilde{a}^s(a'),\theta,e=1,\eta'\right) \tag{11}$$
$$c + a' + p_e - y + T(y,a,c) = a(1+r)$$
$$y = hw_0E_{j=5,e=1}(\theta,\eta=0), \quad a' \geq \underline{a}^s, \quad 0 \leq h \leq 1-\overline{h}, \quad \eta' \sim \Gamma_{j=6,e=1}$$

As indicated in the maximization problem, the agent can borrow up to the limit $\underline{a}^s$ (repaying at interest rate $r^s > r$) or save at rate r. Note that we have assumed that the initial draw of η — the productivity shock — occurs after the college decision. The functional form assumption we make in Section 3 implies that we can evaluate E at the mean value of η (i.e., $\eta = 0$). We assume that work hours and college study hours incur the same disutility.

Once agents have finished their education (be it high school or college), we use $V_j(a,\theta,e,\eta)$ to denote the value of work for an agent of age j with assets a, skills θ, education e, and stochastic labor productivity shock η. It is defined by

$$V_j(a,\theta,e,\eta) = \max_{c,a',h} u(c,h) + \beta\mathbb{E}V_{j+1}(a',\theta,e,\eta'), \tag{12}$$
$$c + a' - y + T(y,a,c) = \begin{cases} a(1+r) & \text{if } a \geq 0 \\ a\left(1+r^b\right) & \text{if } a < 0 \end{cases}$$
$$y = hw_eE_{j,e}(\theta,\eta), \quad a' \geq \underline{a}_{j,e}, \quad 0 \leq h \leq 1, \quad \eta' \sim \Gamma_{j,e}(\eta)$$

As indicated, the agent can borrow up to $\underline{a}_{j,e}$, repaying at $r^b > r$, and the return on positive savings is $1+r$.

To sum up, at the beginning of period $j=5$, V_j^{sw} is the value of an agent who chooses between working

[15] Thus, we can transform college loans into regular bonds using the following formula:

$$\tilde{a}^s(a') = a' \times \frac{r^s}{1-(1+r^s)^{-5}} \times \frac{1-\left(1+r^b\right)^{-5}}{r^b}$$

Stafford college loans, the ones on which our estimation is based, have various repayment plans during which the borrower pays a fixed amount each month. Even though repayment plans typically last 10 years, they can be extended to up to 25 years. As in Abbott et al. (Forthcoming), we choose 20 years for our fixed payment plan.

[16] This feature is useful in the quantitative analysis since otherwise too many students would work full time while in college, reducing the importance of parental transfers or of borrowing to finance education. According to the National Center for Education Statistics, less than 50% of full-time students work while in college and approximately only one-fourth of these working students work more than 35 hours a week.

(as a high-school graduate) versus a college education, i.e.,

$$V_j^{sw}(a,\theta,\varepsilon) = \max\left\{\mathbb{E}_{\eta|e}V_j(a,\theta,e=0,\eta), V_j^s(a,\theta,e=1) - \kappa(\varepsilon,\theta)\right\} \tag{13}$$

where the disutility from college is given by a scalar κ that depends both on a taste parameter ε (whose distribution depends potentially on parental education) and on the agent's own skills θ.

Working Stage and Children After education is completed (i.e., either after high school — so, at the beginning of period 5 — or the end of college — so, at the beginning of period 6) and until retirement at the end of period 17, the agent works and their individual problem is equivalent to (12) except for those special periods in which the agent decides (i) investment in the child's skills and (ii) a monetary transfer to the child right before the child begins college. We now describe the maximization problems associated with these decisions in detail.

Investment in child's skills: Agents are assumed to have one child in period $j = 8$ (age 28).[17] In that period and the subsequent one, the agent has to choose the number of hours τ and resources ("money") m to invest in the development of the child's skills. These are assumed to have a cognitive and non-cognitive component, i.e., $\theta_k = \left\{\theta_{k,c}, \theta_{k,nc}\right\}$.[18] The child's initial draw of skills is stochastic and potentially a function of the parent's skill level. The skill development function below consists of two nested CES functions (for cognitive c and non-cognitive nc skills):

$$\theta'_{k,q} = \left[\alpha_{1qj}\theta_{k,c}^{\varphi_{jq}} + \alpha_{2qj}\theta_{k,nc}^{\varphi_{jq}} + \alpha_{3qj}\theta_c^{\varphi_{jq}} + \alpha_{4qj}\theta_{nc}^{\varphi_{jq}} + \alpha_{5qj}I^{\varphi_{jq}}\right]^{1/\varphi_{jq}} \exp\left(\nu_q\right) \tag{14}$$

for $q \in \{c, nc\}$, where parental investments I are

$$I = \bar{A}\left[\alpha_m m^\gamma + (1-\alpha_m)\tau^\gamma\right]^{1/\gamma} \tag{15}$$

The outer CES, equation (14), is based on Cunha et al. (2010). The child's skill level next period, θ'_k, depends upon the child's current (cognitive and non-cognitive) skill level θ_k, parental (cognitive and non-cognitive) skills θ, and parental investments I, as well as an idiosyncratic shock ν. As in Daruich (2019), parental investments are modeled explicitly to incorporate τ and m in the inner CES. Note that the formulation above implies that parental investment cannot be targeted to a particular type of skill.

We assume that child skills can be affected only in the first two periods of their lives (i.e, in periods $j = 8$ and 9 of the parent's life).[19] Thus, in addition to standard choices of consumption, savings and labor supply, the agent in those two periods also chooses how much time τ and money m to invest in

[17] The average age of first birth for married women in 2007 was 27.97 according to the National Center for Health Statistics.

[18] Although this is a potentially more complex view of skill formation than what would otherwise be optimal given our purposes, it has the advantage of allowing us to use the estimates of Cunha et al. (2010) for the parameters of the skill production function.

[19] This assumption simplifies the solution but is also in line with the evidence on early childhood development literature which finds that skills are considerably less malleable for older children (e.g., Cunha et al., 2010).

the child's skill development as shown in the value function below:[20]

$$V_j\left(a,\theta,e,\eta,\theta_k\right)=\max_{c,a',h,\tau,m} u\left(c,h\right)-v\left(\tau\right)+\beta\mathbb{E}V_{j+1}\left(a',\theta,e,\eta',\theta_k'\right), \tag{16}$$

$$c+a'+m-y+T\left(y,a,c\right)=\begin{cases} a\left(1+r\right) & \text{if } a\geq 0\\ a\left(1+r^b\right) & \text{if } a<0\end{cases}$$

$$y=hw_eE_{j,e}\left(\theta,\eta\right),\quad a'\geq \underline{a}_{j,e},\quad 0\leq h+\tau\leq 1,\quad \eta'\sim\Gamma_{j,e}(\eta)$$

$$\theta'_{k,q}=\left[\alpha_{1qj}\theta_{k,c}^{\varphi_{jq}}+\alpha_{2qj}\theta_{k,nc}^{\varphi_{jq}}+\alpha_{3qj}\theta_{c}^{\varphi_{jq}}+\alpha_{4qj}\theta_{nc}^{\varphi_{jq}}+\alpha_{5qj}I^{\varphi_{jq}}\right]^{1/\varphi_{jq}}\exp\left(\nu_q\right)$$

$$m\in\{m_1,m_2,...\},\quad \tau\in\{\tau_1,\tau_2,...\},\quad \nu_q\sim N(0,\sigma_{j,\nu_q}),\quad q\in\{c,nc\}$$

$$I=\bar{A}\left[\alpha_m m^{\gamma}+(1-\alpha_m)\tau^{\gamma}\right]^{1/\gamma}$$

After these two periods, the child's skills are assumed to be constant and the agent's maximization problem returns to that given in (12) but with an additional state variable θ_k.

Transfer to child: At the beginning of period $j=12$ (period $j=5$ for the child) but prior to knowing their child's κ realization (i.e., the draw of ε), the parent decides the size of the monetary transfer $\hat{a}$ to their child.[21] We denote the value function at in this sub-period by V_{transfer}. Importantly, the transfer is restricted to being non-negative — i.e., parents can neither bequeath debt to their child nor borrow against their child's future income. When making this choice, the parent is assumed to know their own income shock realization.

$$V_{\text{transfer}}\left(a,\theta,e,\eta,\theta_k\right)=\max_{\hat{a}} V_{j=12}\left(a-\hat{a},\theta,e,\eta'\right)+\delta\mathbb{E}V^{sw}_{j'=5}\left(\hat{a},\theta_k,\varepsilon\right), \tag{17}$$

$$\hat{a}\geq 0,\quad \varepsilon\sim N(\bar{\varepsilon}_e,\sigma_\varepsilon)$$

Notice that, unlike in equation (16), the value function in this stage now includes the child's continuation value $V^{sw}_{j'=5}$ where j' denotes the child's period-age. Note that δ measures the degree of parental altruism towards their child. This is the last period in which the parent's choices affects their child. Lastly, note that since the value function is written recursively, this implies that at every period in which parental choices affect her child's outcomes — i.e., all preceding periods — the utility of all her descendants have been taken into account. This formulation embeds the parental altruism motive. After the agent's child becomes independent, the individual problem reverts to (12), so the child's state variables are no longer present.

The Retirement Stage At $j=18$, the agent retires with two sources of income: savings and retirement benefits. To simplify the problem, we assume that retirement benefits depend only on the agent's

[20]The choice of time and money is made within a discrete set of possible alternatives for computational reasons. We assume that the disutility from time τ is separable because, examination of the PSID CDS cross-sectional data suggests that individuals who spend more time with their children reduce leisure time instead of hours worked.

[21]The assumption that the child's taste is not perfectly known to the parent helps make the problem smoother which is useful for computational reasons.

education and skill level, a proxy for average lifetime income. Agents no longer work ($h = 0$) nor borrow. Formally, the problem at the age of retirement is

$$V_j(a, \theta, e) = \max_{c,a'} u(c, 0) + \beta V_{j+1}(a', \theta, e) \tag{18}$$
$$c + a' + T(\pi(\theta, e), a, c) = \pi(\theta, e) + a(1 + r)$$
$$a' \geq 0$$

where π indicates the retirement benefit.

Definition of Stationary Equilibrium The model has 20 overlapping generations alive at any time period and is solved numerically to characterize the stationary equilibrium allocation. Stationarity implies that we study an equilibrium in which the cross-sectional distribution for any given cohort of period-age j is invariant over time periods. Particularly important is that the distribution of initial states is determined by the choices of the older generations. In equilibrium, households choose education, consumption, labor supply, parental investment in child skills in the form of time and resources, and parental transfers such that they maximize their expected utility taken prices as given; firms maximize profits; and prices (wages of each education group and the interest rate) clear markets.

We do not require that the government budget be balanced as the government may have other non-modeled expenses, G. When a new policy such as UBI is introduced, however, we require that any net additional expenses be matched by additional revenue.[22] Thus, G will be defined in the stationary equilibrium as a residual (see Appendix A for the expression).

2.3 Role for UBI

In the next section, we estimate that lump-sum transfers to all households, ω, is approximately \$2,400 per year (in year 2000 dollars). Providing UBI, therefore, is an increase in ω above this initial level. It is useful to think beforehand why this policy may improve upon the status quo or may be detrimental. In addition, given the existence of both cross-sectional and cross-cohort heterogeneity, who might one expect to be helped/hurt?

There are several sources of inefficiency in the environment. First, an agent's inability to borrow fully against their own future income or to insure against future outcomes leads to imperfectly smooth consumption. This consequence of capital market imperfections is well understood, and a UBI policy can facilitate self-insurance and provide a lower variance of consumption. Poorer agents, furthermore, would in addition value the increase in redistribution implied by this policy. Second, in addition to consumption smoothing, a UBI policy makes college easier to finance, especially for poorer agents, rather than relying solely on the parental transfer, borrowing, or working at a relatively low wage. Lastly, UBI

[22] We leave the exact way in which this is done to the policy evaluation in section 4.

allows parents to increase their investment in their child's skill formation by providing them with additional income at an age in which they are relatively poorer and face more binding credit constraints. Overall, one might expect that the agents who would primarily benefit would be those who are poorer and younger.

Of course, any positive effects of UBI must be weighed against the cost of increased distortionary taxation. A higher labor income tax will, ceteris paribus, make a college education less attractive than before. If this depresses the proportion of agents who acquire a college education, this will tend to lower high-skill wages as well. Overall, how the benefits stack up against these additional costs is a quantitative question. The next section estimates the stationary equilibrium of the model which we will then use to provide a quantitative evaluation of a UBI policy.

3 Estimation

In this section we describe how we parameterize and estimate the model. The model is estimated using simulated method of moments to match standard moments as well as more novel ones for the US in the 2000s. Some of the parameters can be estimated "externally," while others must be estimated "internally" from the simulation of the model. For these, we numerically solve for the stationary distribution of the economy and calculate the moments of interest. Tables 2 and 3 summarize the parameters and moments used. After estimating the model, we validate the model using non-targeted moments, including estimates of the elasticity of labor supply to non-labor income, labor income inequality, and the net return to college. In addition, we use the model to assess the effect on child skills of cash transfers to parents and contrast this with evidence from exogenous variation in cash transfers via changes in EITC (from Dahl and Lochner (2012)).

Mapping the model to the data We use three primary data sources: (i) the Panel Study of Income Dynamics (PSID), surveys between 1968 and 2016; (ii) the Child Development Supplement (CDS) to PSID, surveys of 1997, 2002 and 2007; and (iii) the 1979 cohort of the National Longitudinal Survey of Youth (NLSY79), surveys between 1979 and 2012.

We select a population for which the model can be taken as a reasonable approximation to household behavior. The model is estimated to match household-level data, taking an agent in the model as corresponding to a household with two adults in the data. A child corresponds to two children in the data. In this way, every household in the model has one household as offspring.

The model has several outcomes that are the result of an agent's decisions. To map these to household observations in the data we do the following. An agent's labor income is the sum of the two adults' labor income in the data.[23] Similarly, hours worked are the sum of hours worked by the two adults.

[23]Following standard practice, we drop those household observations in which hourly wages are less than half the minimum wage.

Education and age, on the other hand, are the education level and age of the head of household. Furthermore, as there is no household formation decision (marriage, cohabitation, or divorce) in the model, we restrict our samples to households with two adults.[24] This avoids as well differences in income and time availability that arise from comparing couples to single parents. Lastly, we simplify matters by dropping individuals that did not complete high-school.[25] We define college graduates as those with at least 4 years of college. Those with a high-school degree but less than 4 years of college are considered high-school graduates.[26] Borrowing constraints of adult households are by education (again, of household head, and correspond to twice the individual amount found in the data).

In a similar spirit, money invested (per child) by the parent in the child's skill formation must be multiplied by two for use in the quantitative model whereas the time investment in children is taken as a total amount of time spent by both parents in the data. The price of college and the constraint on the maximum level of subsidized loans corresponds to individual levels in the data and again must be multiplied by two to obtain the relevant values for the agent/household.

Life cycle Recapitulating, a period in the model is four years. Individuals reach independence at period-age $j = 5$ (equivalent to age 16) with a high-school education. They can decide to go to college (one period), and so the education stage finishes no later than $j = 6\,(20)$. Parental time and money investment decisions are made the period in which the child is born $j = 8$ (age $28 - 31$) and the period after. At age $j = 12$ (age $44 - 47$), the agent chooses the assets to transfer to the child and the latter takes the college decision. Retirement occurs at $j = 18\,(68)$. Agents live through period-age $j = 20$, which means that death is assumed to occur for all agents at the beginning of period-age $j = 21\,(80)$.

Prices All prices are in 2000 dollars. These are normalized, using the TFP parameter A, such that the average annual household income of a high school agent in period 13 (age 48) is equal to one in the model. This represents \$58,723 in the data. The yearly price of college is estimated using the Delta Cost Project to be \$13,176 per household (\$6,588 per person).[27]

Borrowing constraints Based on self-reported limits on unsecured credit by family from the Survey of Consumer Finances, Daruich (2019) estimates the borrowing limits for working-age *households* to

[24] We do not follow marital transitions nor insist that the household head have the same partner every period. As shown in Fernández and Wong (2017), incorporating endogenous marriage and divorce decisions, while important, vastly increases computational complexity.

[25] Although this somewhat reduces the size of our samples (the PSID sample by 11% and the NLSY by 6%), it decreases the computational complexity as in this way we can more easily restrict education levels to only two.

[26] An alternative approach that keeps the computational requirements unchanged (but also keeps high-school dropouts in the sample) would be to divide the education groups in non-college vs. college. For the purposes of the results, the main differences would stem from the wage processes. Following this alternative, we find similar estimates for the wage process: the returns to skill, wage shocks processes, and the out-of-work shocks (discussed later) are almost identical. The age profile is less steep, however, by approximately 10%.

[27] The Delta Cost Project Database is a longitudinal database that studies colleges revenue and expenditures. Our estimate is based on 4-year private not-for-profit and public colleges, taking into account grants and scholarships, such that only privately borne tuition costs are considered. Recall that each agent has one child (which in terms of thinking about the data, means multiplying the child's expenditures by two.

be $\{-20,000, -34,000\}$ for high-school and college graduate households, respectively. We use these as estimates for $\underline{a}_{j,e}$. The (annualized) wedge for borrowing is set to 10%, which is the average among the values for credit card borrowing interest rates (net of r and average inflation) reported by Gross and Souleles (2002).

Taxes and Pension Benefits The tax function is assumed to be $T(y, a, c) = y - \lambda y^{1-\tau_y} + \tau_a ar\mathbf{1}_{a\geq 0} + \tau_c c - \omega$. Based on McDaniel (2007), we set $\tau_a = 0.27$ and $\tau_c = 0.07$. Parameter τ_y helps determine the progressivity of the marginal tax rate. We use the preferred estimation of $\tau_y = 0.18$ from Heathcote et al. (2017). The main disadvantage, for our purposes, is that they they do not restrict the sample to two-adult households and that they include capital income (as they do not have capital in their model) which we allowed to be taxed at a different rate as suggested by the literature.[28] We can check whether we would obtain a significantly different estimate by using the NBER's TAXSIM (Feenberg and Coutts, 1993) to estimate after-tax income for two-adults households with different levels of (only) labor income, by US state in the year 2000. Using this data, we follow the steps of Heathcote et al. (2017) and estimate $\tau_y = 0.20$, consistent with their estimates. More importantly, this suggests that abstracting from capital income and focusing on two-adults households does not significantly change the progressivity estimates. Lastly, λ is estimated using simulated method of moments to match the proportion of labor income that is paid in taxes (i.e., the labor-income tax rate) of 22%, the average over the annual labor-income tax rates estimated by McDaniel (2007) over the period 1985–2003.[29]

Figure 1 of Heathcote et al. (2017) graphs households' pre versus post-tax income and shows that low-income households tend to have higher after-tax income than what the authors' estimates of the tax function without a lump-sum component suggests. Incorporating a lump-sum transfer ω and estimating the latter so as to match a measure of income redistribution – the ratio of the variance of pre-tax total (i.e., labor plus savings) income to after-tax total income – is one way to indirectly obtain its value. We do this and find ω equivalent to \$2,400 per year. Alternatively, we can use the PSID to calculate the difference between after-tax-and-transfers annual income and pre-tax annual income for low-income households with two adults and two children. For households in the bottom 1%, we find that this difference is on average \$2,475; for households in the bottom 5%, the difference is on average \$2,272. These values suggest that the estimate of $\omega = \$2,400$ is in line with the observed transfers received by low-income parents.

[28] Although both capital and labor income are jointly taxed in the US tax code, we allow them to be taxed at different rates as is standard in the quantitative macro literature (e.g., Kaplan, 2012; Krueger and Ludwig, 2016; Luduvice, 2019; Abbott et al., Forthcoming). This allows for the fact that most households' assets (e.g., housing) do not generate income and, therefore, are not subject to capital income taxes. Instead, most of these assets are, if anything, subject to capital gains taxes. Although a model with more than one asset can incorporate both capital income and capital gains taxes separately, our model has one asset and thus τ_a is set, following the literature, to capture the relevant mix of taxes on capital returns.

[29] More precisely, let $s_j \in S_j$ and $\mu = \{\mu_j\}$ be the age-specific state vector of an individual of age j and the Borel sigma-algebras defined over those state spaces, respectively. Then, the labor tax rate in the economy at time t is defined as $\frac{\sum_{j=5}^{17}\int_{S_j}\left(y-\lambda y^{1-\tau_y}-\omega\right)d\mu_j}{\sum_{j=5}^{17}\int_{S_j} y d\mu_j}$. Note that the integral is over the cross-section of adult agents alive at time t, where the time subscript has been suppressed everywhere.

The pension replacement rate is based on the Old Age, Survivors, and Disability Insurance federal program. We use education and skill level to estimate the average lifetime income on which the replacement benefit is based.[30]

Intergenerational Skill Transmission We assume that the child development function takes a nested CES form (see equations 14 and 15). The outer CES is based on Cunha et al. and we adopt their parameter values which vary with the age of the child and were estimated using a representative sample.[31] These values indicate that skills are more malleable when children are young, i.e., the elasticity of substitution determined by φ_{jq} is larger the younger the child. Furthermore, in order to use these parameter values we follow the authors in assuming that skills are a vector with two components: cognitive skill and non-cognitive skill. Cunha et al. highlight that abstracting from the two types of skills leads to estimates that suggest that investments on low-skilled children are much less productive (i.e., a more negative φ_{jq}). Thus, θ and θ_k are vectors with a separate entry for each skill.[32] The initial draw of skills is assumed to depend on parent's skills as an AR(1) process, independent for cognitive and non-cognitive skills. For example, the draw of cognitive skills follows

$$\log\left(\theta_{k,c}\right) = \hat{\rho}_c \log\left(\theta_c\right) + \varepsilon_{\theta_{k,c}}$$

where $\varepsilon_{\theta_{k,c}}$ is a shock, independent across skills. The persistence component $\hat{\rho}_c$ is, by definition, equal to $\rho \times \left[\frac{\mathrm{Var}(\log(\theta_{k,c}))}{\mathrm{Var}(\log(\theta_c))}\right]^{0.5}$, where ρ is the correlation between $\log\left(\theta_{k,c}\right)$ and $\log\left(\theta_c\right)$. The functional form is equivalent for the initial draw of non-cognitive skills $\theta_{k,nc}$. We obtain $\mathrm{Var}\left(\log\left(\theta_c\right)\right)$,$\mathrm{Var}\left(\log\left(\theta_{nc}\right)\right)$, $\mathrm{Var}\left(\log\left(\theta_{k,c}\right)\right)$, and $\mathrm{Var}\left(\log\left(\theta_{k,nc}\right)\right)$ directly from Cunha et al. (2010), and internally estimate ρ (which we assume is common across skills) to match the intergenerational persistence of gross income of 0.26, as measured by income rank persistence from Chetty et al. (2014).[33] Given the functional form, the variance of the cognitive skills shock $\varepsilon_{\theta_{k,c}}$, for example, is obtained as $\mathrm{Var}\left(\varepsilon_{\theta_{k,c}}\right) = \mathrm{Var}\left(\log\left(\theta_{k,c}\right)\right) - \hat{\rho}_c^{\,2}\mathrm{Var}\left(\log\left(\theta_c\right)\right)$.

Parental investment in child skills (equation 15) in terms of time and money is made within a discrete set of possible alternatives for computational purposes.[34] We estimate α_m and γ so as to match the following moments on parental investments reported in Daruich (2019), which are based on CDS and Consumer Expenditure Survey (CEX) data. In particular, α_m is estimated to match the average ratio of annual expenditures on children (as measured by child-care expenditures including those on early childhood

[30]See Appendix B.1 for details.

[31]Appendix Table B1 reports the parameter values and standard deviations.

[32]Similarly, α is also a vector.

[33]We use the authors' estimate for children of married parents as this is the closest correspondence to the agents of the model. Chetty et al. (2014) measure household gross income (mainly) based on the 1040 tax return, thus including both labor and capital income. Consequently, to match this moment we also use agents' gross income which includes labor and asset (savings) income. They measure children's income when these are approximately 30 years old, which we replicate in our model using income in age-period $j = 8$. Whereas Chetty et al. (2014) proxy parental income during the time that children were growing up with measures of parents' income from later years, we average parental income over the periods that the child is with their parents $j = 8$ to 11.)

[34]We limit the number of options for time and money to 7 each, i.e., 49 total alternatives.

centers and nannies) to weekly "quality" hours spent by parents with their children (as measured by time reading and playing), whereas γ is estimated to match the correlation between the two variables across parents. Finally, $\bar{A}$ is estimated such that the average level of log cognitive skills in the estimated economy is equal to zero.[35]

Wage Process and Return to Skills We estimate the wage process and return to skills using NLSY and PSID data for households, assuming that the wage process of household i with education e at age j is given by $w^e E^e_{ij}$ with $E^e_{ij} = \epsilon^e_j \psi^e_{ij}$. As noted previously, ϵ^e_j is the age profile for the education group e and ψ^e_{ij} is the idiosyncratic labor productivity. This is assumed to evolve according to:

$$log\left(\psi^e_{ij}\right) = \lambda^e log\left(\theta_{ic}\right) + \eta^e_{ij} \tag{19}$$
$$\eta^e_{ij} = \rho^e \eta^e_{ij-1} + z^e_{ij}, \quad z^e_{ij} \overset{iid}{\sim} N\left(0, \sigma^e_z\right)$$

where θ_{ic} is the agent's level of cognitive skills (one of the elements of θ) and η^e_{ij} is the idiosyncratic shock. An agent's initial productivity shock η^e_0 is drawn from a normal distribution with mean zero and variance $\sigma^e_{\eta_0}$. Allowing the impact of skills on wages to depend on education via λ^e is important to determining the choice of education for agents with different skill levels.

We define wages $w_{i,t}$ for household i in period t as the total labor income from the two adults in the household divided by the total number of hours worked by the two adults. Since the model has 4-year-long periods, we estimate this wage process by averaging observations over 4 years.[36] Using information on the highest degree completed by the head-of-household, we split households into those with at least a college degree and those with at least high-school but less than college. For each education group we use PSID data to obtain the age profile ϵ^e_j using a quadratic polynomial on the age of the head-of-household, controlling for year (defined as the initial year of the 4-year period) fixed effects and selection into work,

$$w_{i,t} = \beta_0 + \beta_1 \text{Age}_{i,t} + \beta_2 \text{Age}^2_{i,t} + \beta_3 X_{i,t} + \gamma_t + \psi_{i,t}$$

where $X_{i,t}$ is the control for selection into work based on a Heckman-selection estimator.[37] Appendix Table B2 shows the results. Armed with the age profile, we can then use (4) to recover ψ^e_{ij} as a residual in the NLSY data.[38] Next, an estimate of λ^e is recovered by regressing our estimate of ψ^e_{ij} against the

[35] We use the same normalization as Cunha et al. (2010) to be consistent.

[36] An alternative, as in Krueger and Ludwig (2016), is to estimate the wage process using yearly data and then transform the estimates to 4-year periods. Appendix Table B4 shows that the estimates obtained this way are very similar. Both methods, however, essentially assume complete markets within a period and, by doing so, may not give sufficient weight to a UBI policy that would diminish the variance of consumption. To evaluate the importance of this limitation, in Section 4.3 we double the variance of the wage shocks, σ^e_z, and examine how this affects the main results.

[37] To control for selection into work we use a Heckman-selection estimator. In particular, we construct Inverse Mills ratios by estimating the participating equation separately for each education group using number of children as well as year-region fixed effects.

[38] We need to use NLSY for this step since the PSID in general does not have information that is pertinent for measures of skills such as an AFQT score. The PSID, instead, is preferred for estimating the age profiles since the age of the sample does not covary perfectly with the year of the survey (as is the case of NLSY).

log of cognitive skills as measured by the AFQT score (i.e., we estimate equation 19). Lastly, the AR(1) process for the residual η (i.e., the shock to the efficiency units in equation 19), is estimated using the standard Minimum Distance Estimator developed by Rothenberg et al. (1971).

Table 1 shows the estimates obtained by the process just described. As can be seen, the returns to skill are twice as large for college workers than high-school ones. Note that agents with college education draw their initial productivity from a distribution with a slightly lower variance than high-school agents, as indicated by the last row of Table 1, but shocks received later in life have a larger variance for college workers than high-school workers.

Table 1: Returns to skill and wage process by education group

	(1) High School	(2) College
λ^e	0.471	1.008
	(0.0335)	(0.0768)
ρ^e	0.914	0.967
	(0.0008)	(0.0009)
σ^e_z	0.032	0.046
	(0.0002)	(0.0002)
$\sigma^e_{\eta_0}$	0.051	0.047
	(0.0003)	(0.0003)

Source: PSID (1968–2016) and NLSY (1979–2012). A period is 4 years long. Cognitive skills (from NLSY) are measured using log(AFQT), i.e., the natural logarithm of the AFQT raw score. The regressions include year fixed effects. Standard errors in parentheses.

Out-of-Work Shock A distinctive feature of the model is that agents may be hit by a very bad shock that essentially forces them to exit the labor force for an entire period. Using PSID data, we estimate the transition probabilities between the out-of-work and working states for different education-age groups using yearly household labor-income data.[39] We estimate the following Probit model:

$$\Pr\left(\text{Working}_{i,t}\right) = \Phi\big(\alpha + \beta_1 \text{Working}_{i,t-1} \times \text{age}_{i,t} + \beta_2 \text{Working}_{i,t-1} \times \text{age}^2_{i,t} + \beta_3 \text{Working}_{i,t-1} + \beta_4 \text{age}_{i,t} + \beta_5 \text{age}^2_{i,t} + \gamma_t + \text{gender}_i + \varepsilon_{i,t}\big),$$

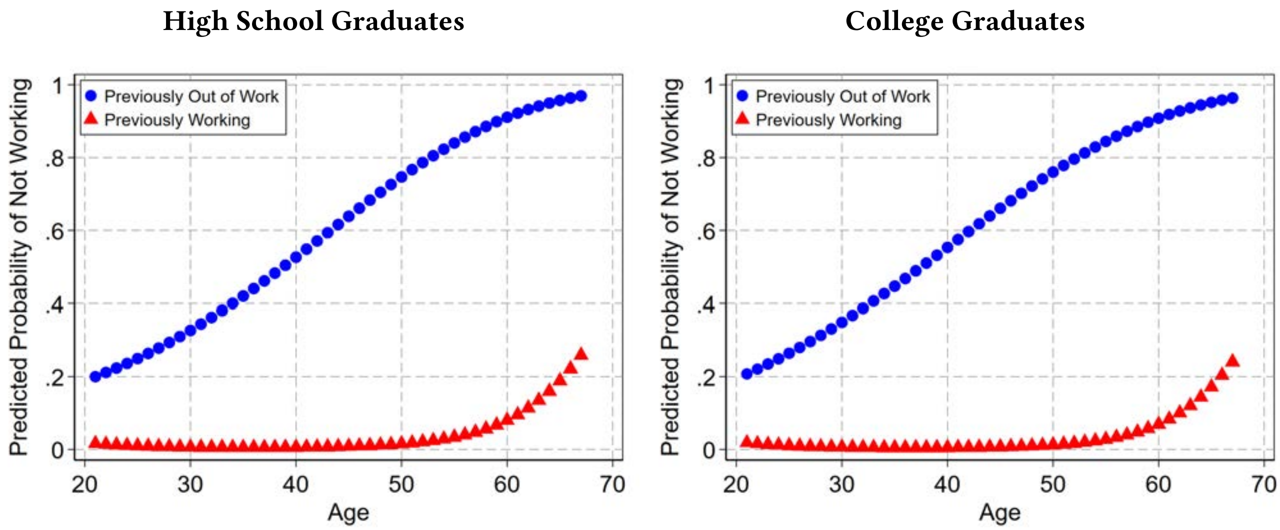
where $\text{age}_{i,t}$ and gender_i are the age and gender of the household head, respectively, and γ_t is a year fixed effect. A household is coded as not working if both adult members are not working that year. Figure 2 shows the estimated transition probabilities by age and education.[40]

We then use these to calculate the transition probabilities for the model periods (e.g., the probability of being out of work in period j corresponding to ages 44-47 given that the household worked in period

[39]We do not use PSID years after 1996 since the surveys are biennial after that year.
[40]See Appendix Table B3 for the estimated coefficients.

$j-1$ is calculated as $Pr(NW_{t=44}|W_{t=43}) \prod_{t=45}^{t=47}(NW_t|NW_{t-1})$, where t indicates age). We conservatively assume that this out-of-work state corresponds to household not earning labor income during an entire period (i.e., for 4 years in the data). Figure 3 shows the implied transition probabilities by age and education. Note that individuals with different education levels have similar probabilities of entering the "out-of-work" state and of remaining in that state in the following period. Both probabilities are monotonically increasing with age.

Figure 2: Data: Yearly Out-of-Work Transition Probabilities



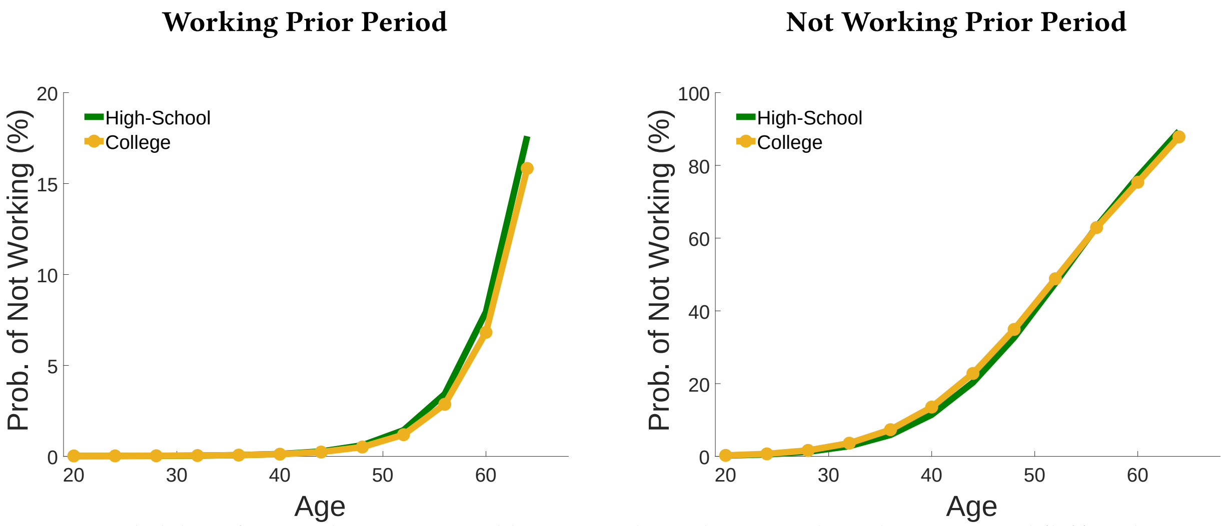
Source: PSID, 1968-1996.

The out-of-work shock is included in η_{ij}^e with a value of $\eta_{ij}^e = -\inf$, which makes the hourly wage zero. The probability of entering this state next period depends on the age and education of individual (as shown by the left panel of figure 3), but is otherwise assumed to be independent of the current value of $\eta_{ij}^e > -\inf$. The probability of exiting the out-of-work state is likewise given by the right panel of figure 3, which also depends on age and education. Furthermore, we assume that individuals that exit the out-of-work state start with the lowest value of $\eta_{ij}^e > -\inf$ since the data shows that these individuals tend to have low earnings relative to their education/age groups upon re-employment.[41] Our estimates imply that the share of individuals in the out-of-work state is 0.1% when they are 36 years old and increases to 10.5% by the time households are 60 years old.[42]

[41]The lowest value of η_{ij}^e is age- and education-dependent in our wage process. Moreover, these values depend on the discretization procedure. In our procedure (based on the Rouwenhorst method), these values imply that wages are approximately between 27 and 58% below the age-education group average. Using the PSID data, we estimate that the wages of households who are currently working but were not working the previous year to be, on average, 29% lower than those of households who were working, controlling for age and education.

[42]One may be concerned that these estimates are capturing retirement rather than involuntary non-employment. We evaluate this concern by comparing our estimates to a particular form of involuntary non-employment, i.e., disability. Using Social Security data, Hosseini et al. (2018) estimates that the share of individuals with disability increases over the same age period, from a base of 1.8% to 13.9%. Although our estimates are not directly comparable, they suggest that they are unlikely to be a product mainly of joint retirement decisions.

Figure 3: Model: Period (4-Year) Out-of-Work Transition Probabilities



Notes: The probability of not working next period by age, conditional upon working the prior period (left) and not working the prior period (right).

School Taste In this class of models it is difficult to match the intergenerational persistence of education without introducing something like school tastes/psychic costs of education, (e.g., Abbott et al., Forthcoming; Krueger and Ludwig, 2016). We assume that school (dis)taste in utility terms is given by

$$\kappa\left(\varepsilon,\theta\right)=\exp\left(\alpha+\alpha_{\theta_c}log\left(\theta_c\right)+\alpha_{\theta_{nc}}log\left(\theta_{nc}\right)+\varepsilon\right) \tag{20}$$

This specification allows higher-skilled individuals to have (on average) lower levels of school distaste if $\alpha_{\theta_c}<0$ and/or $\alpha_{\theta_{nc}}<0$. Parental education also matters as ε is an idiosyncratic shock which is assumed to follow a normal distribution $N\left(\bar{\varepsilon}_{e_p}-\frac{\sigma_\varepsilon^2}{2},\sigma_\varepsilon\right)$ whose mean depends on the parent's education. Without loss of generality, we assume that $\bar{\varepsilon}_{e_p}$ is zero for children of high-school graduates. Although the parameters are simultaneously estimated to match the moments in the data, it is intuitive to think that α is estimated to match the college graduation share from NLSY; α_{θ_c} and $\alpha_{\theta_{nc}}$ are estimated to match the relation between college graduation and cognitive and non cognitive skills, respectively, as measured by regressing college graduation on the log of cognitive (AFQT score) and non cognitive (Rotter's locus of control score) skills; σ_ε is estimated to match the variance in college graduation after controlling for skills (i.e., the variance of the residual in the previously mentioned regression); and $\bar{\varepsilon}_{e_p}$ is estimated to match the intergenerational persistence of education (measured according to the determinant of the intergenerational education transition matrix from child-mother pairs in the PSID-CDS data).[43] We use the mother's education instead of the education of the household head since the father's education is missing for approximately 26% of the children in the our final PSID-CDS sample.[44]

[43]AFQT and Rotter's locus of control are common measures of cognitive and non-cognitive skills, respectively. Given that we use Cunha et al. (2010) estimates for our skill development function, we highlight that they also use AFQT and Rotter's locus of control scores in the measurement equation of their estimation.

[44]Restricting the sample to those with education not missing for household head and using the latter's education level, we obtain a slightly more persistent dynamic with a determinant of 0.62 (and standard error of 0.035) instead of 0.7 (0.034).

See Table 3 for the values of these moments.

College loans College students have access to subsidized loans at rate $r^s = r + \iota^s$. According to the National Center for Education Statistics report "Student Financing of Undergraduate Education: 1999-2000," among the undergraduates who borrow, nearly all (97%) took out federal student loans, while only 13% took out non-federal loans. Moreover, the average loan value was similar for both federal and non-federal loans. Since average values were similar but federal loans were significantly more common, we focus on federal loans for our model estimation. Among federal loans, the Stafford loan program was the most common: 96% of undergraduates who borrowed took out Stafford loans. As there are various types of Stafford loans, we use the weighted average interest rate to set $\iota^s = 0.009$ (see Daruich and Kozlowski, 2020). The borrowing limit in college is set to match the cumulative borrowing limit on Stafford loans ($23,000).[45]

Preferences As noted, we specify the period utility over consumption and labor as $u(c, h) = \frac{c^{1-\gamma_c}}{1-\gamma_c} - \mu \frac{h^{1+\gamma_h}}{1+\gamma_h}$. We follow the literature and assume that $\gamma_c = 2$ and $\gamma_h = 3$ (i.e., the Frisch elasticity is 1/3).[46] μ is estimated to match the weekly average hours of labor from the PSID sample over the ages of 20-64. Recall that parental disutility from time spent with their children is linear, i.e., $v(\tau) = \xi\tau$. ξ is estimated to match estimated average weekly hours that parents spend with their children engaged in reading and playing over the ages of 0-3. Finally, the altruism factor δ is estimated to match the average monetary transfers from parents to children, as estimated from the Rosters and Transfers supplement to the PSID.[47]

Aggregate production function We set $\alpha = \frac{1}{3}$ in the aggregate Cobb-Douglas production function and the capital depreciation rate $\delta_k = 23.6\%$ (i.e., 6.5% annually). We use the CPS from 1962-2015 to estimate $\Omega = 0.43$ and $s = 0.53$ (in equation 6) following the standard procedure of regressing the variation of wage bills with the change in labor supply as suggested by the first order conditions of the representative firm (e.g., Katz and Murphy, 1992; Heckman et al., 1998).

Using only families with two parents and two children (which reduces the sample size by almost 75%) as well as the head of household's education leads to a determinant of 0.65 (0.063).

[45] Recall that a child represents a future household. Thus the child is able to borrow twice the individual limit (i.e., $2 \times \$23,000$) but also faces twice the price of college.

[46] See Meghir and Phillips (2010) for a discussion of estimates of the Frisch elasticity.

[47] Daruich (2019) estimates the average total transfers received by children when they are between the ages of 17 and 26 and obtains an estimate of total parental transfers per child of $48,381, equivalent to 75% of average annual household income. The transfer data include small and large (e.g., to buy houses or cars) transfers, in-kind transfers (i.e., college tuition), and estimates for housing costs if the child lives with the parents. See cited paper for details. Note that we will match twice that level in the model, as a child corresponds to two children in the data.

3.1 Simulated Methods of Moments: Results

Table 2: Estimation: Externally calibrated parameters

Parameter	Value	Description	Source
Taxes			
τ_a	0.27	Tax rate on capital returns	McDaniel (2007)
τ_c	0.07	Tax rate on consumption	McDaniel (2007)
τ_y	0.18	Progressivity of labor income tax	Heathcote et al. (2017)
Borrowing Limits			
$\underline{a}^s$	0.18	For college students: \$23,000 × 2	Stafford Loans
$\underline{a}_{j,0}$	0.08	For high-school households: \$20,000	Survey of Consumer Finances
$\underline{a}_{j,1}$	0.14	For college households: \$34,000	Survey of Consumer Finances
Borrowing Rates			
ι	0.10	Wedge of 10% (relative to r)	Gross and Souleles (2002)
ι^s	0.01	Wedge of 1% (relative to r)	Daruich and Kozlowski (2020)
Preferences			
β	0.92	Annual discount rate of 0.98	Standard
γ_c	2	Intertemporal elasticity of substitution of 1/2	Standard
γ_h	3	Frisch elasticity of 1/3	Meghir and Phillips (2010)
Aggregate Production Function			
A	4.18	Average annual income of high-school household, age 48	Normalization
α	1/3	Labor income share of 1/3	Standard
δ_k	0.24	Annual depreciation rate of 6.5%	Standard
Ω	0.43	Substitutability in aggregate labor H	CPS (1962–2015)
s	0.53	High-school weight in aggregate labor H	CPS (1962–2015)

Notes: For the parameters relevant to pension benefits, see Appendix B.1; for those relevant to intergenerational skill transmission, see Appendix B.2; for those relevant to the wage process, out-of-work shock, and return to skills, see Table 1, Figure 2, and Figure 3.

Table 2 provides a summary of the parameters that are externally calibrated. The remaining fourteen parameters of the model are estimated using simulated method of moments. Recapitulating, δ relates to the degree of altruism, whereas μ and ξ are the disutility of labor and of the time spent with children, respectively. α, α_θ (vector of two parameters), $\bar{\varepsilon}$, and σ_ε relate to the distribution of school taste and its relation to skills and parental education. ρ determines the intergenerational persistence of the initial draw of skills. $\bar{A}$, α_m, and γ relate to the effect of parental time and money investments in building skills. Finally, λ and ω relate to the government's average tax rate and redistribution of income, respectively.

We use a Sobol sequence to estimate the model in a fourteen-dimensional hypercube in which parameters are distributed uniformly and over a "large" support. This provides a global method to find potentially good combinations of parameters. Table 3 shows the estimated parameters and the corresponding moments in the simulated economy.

Table 3: Estimation: parameters and moments

Parameter	**Value**	**Description**	**Moment**	**Data**	**Model**
Preferences					
μ	136.8	Mean labor disutility	Avg. hours worked	62.5	63.1
δ	0.44	Altruism	Parent-to-child transfer as share of income	0.75	0.78
School Taste: $\kappa(\varepsilon, \theta) = \exp\left(\alpha + \alpha_{\theta_c} log(\theta_c) + \alpha_{\theta_{nc}} log(\theta_{nc}) + \varepsilon\right)$; $\varepsilon \sim N(\bar{\varepsilon}_{e_p}, \sigma_\varepsilon)$; $\bar{\varepsilon}_{e_p=0} = 0, \bar{\varepsilon}_{e_p=1} = \bar{\varepsilon}$					
α	5.41	Avg. taste for college	College share	33.1	29.9
α_{θ_c}	-0.42	College taste and cog. skills relation	College: cog skills slope	0.23	0.23
$\alpha_{\theta_{nc}}$	-1.24	College taste and noncog. skills relation	College: noncog skills slope	0.16	0.16
σ_ε	2.59	SD of college taste shock	College: residual variance	0.20	0.18
$\bar{\varepsilon}$	-1.89	Draw of school taste: mean by parent's education	Intergenerational persistence of education	0.70	0.69
Investment in Skill Formation: $I = \bar{A}\left[\alpha_m m^\gamma + (1-\alpha_m)t^\gamma\right]^{1/\gamma}$					
ξ	0.03	Parental disutility of time with children	Avg. weekly hours with children	18.0	15.3
$\bar{A}$	35.7	Productivity normalization	Average log-skills	0.0	0.0
α_m	0.97	Money productivity	Ratio of money to hours	214	191
γ	-0.53	Money-time substitutability	Money-time correlation	0.93	0.95
ρ	0.38	Initial draw of skills: correlation with parents' skills	Intergenerational persistence of income	0.26	0.24
Taxes					
λ	0.79	Tax function	Avg. labor tax rate	0.22	0.22
ω ($\times 10^2$)	4.11	Lump-sum transfer	Income variance ratio: Disposable to pre-gov	0.69	0.71

Notes: See the text for definitions and data sources. Parent-to-child transfers reported here are per child. Thus, the mean transfer received by an agent in the model is twice the amount reported.

As can be seen from the table, the model provides a good fit of the data. The education distribution and its correlation with skills and parental education are close to the data estimates. Average time working and with children are successfully matched. The relation between money and time investments is well captured in the model. Finally, the characteristics of the current tax system in the US is well matched: average tax rates and income redistribution, as measured by the ratio of the variances of log disposable-income and log pre-government-income, (as well as the progressivity of the tax function) are in line with the data. The average marginal labor tax rate is 35.9%. It increases from 28.6% for the lowest quintile of the distribution of labor income, to 35.5% for the middle quintile, and is 43.6% for the highest quintile. The cutoff level of labor income for which households go from receiving net positive transfers to net negative transfers (ignoring capital and consumption taxation) is $26,822 or at 37% of average household income.

3.2 Validation

We examine the validity of the estimated model in two ways. First, we can contrast non-targeted model moments with data moments, choosing those that are informative of the fit of the model in important dimensions for the evaluation of a UBI policy. Second, we use results from two studies of cash transfer programs (the closest comparison we could find to UBI) on labor supply and on child development and compare them to model predictions obtained using similar policies.

Table 4: Validation: Non-Targeted Moments

Moment	Data	Model
Investments in Children (Daruich, 2019)		
Log weekly hours on log parent income	0.05–0.12	0.25
Log annual expenditures on log parent income	0.39–0.63	0.93
Weekly hours on college ed. parent	2.5–3.7	2.9
Annual expenditures on college ed. parent	666–730	715
Labor Income Inequality (PSID)		
Gini	0.30	0.30
Top-Bottom Labor Income Ratio	3.8	3.2
Labor Income Share: 1st Quintile	5.8%	8.0%
Labor Income Share: 2nd Quintile	12.7%	13.7%
Labor Income Share: 3rd Quintile	17.6%	17.1%
Labor Income Share: 4th Quintile	23.4%	23.0%
Labor Income Share: 5th Quintile	40.6%	38.3%
Savings (Inklaar and Timmer, 2013)		
Capital-Output Ratio (annualized)	≈ 3	3.1
Net Return to college (Heckman et al., 2006)		
Yearly return	$\approx 10\%$	8.3%

Notes: Parental investment estimates (OLS regressions) are obtained using families in the CEX (for expenditures) and PSID Child Development Supplement data (for hours). The top-bottom income ratio is that of the average income of those in the top 80–95 percentiles and those in the bottom 5–20 percentiles (PSID). See text for other definitions.

Table 4 summarizes the first validation results, i.e., those from non-targeted moments. Starting with investments of time and money in children, we can compare with range of estimates obtained in Daruich (2019) using CEX and CDS data as reported in Table 4.[48] The data shows that college-educated households and/or those with greater labor income invest more in their children (over the ages of 0-7), a feature shared by the estimated model. The first two entries in this panel are the coefficients obtained on the log of parental income in two separate regressions (log of weekly hours with children and log

[48] The exact estimate depends on whether the whole sample or only the (much smaller) sample of households with two children and two adults is used, hence we report the range.

of annual expenditures on children), which are positive in both the model and data. The coefficients, however, are somewhat larger in the model than the data, which may be due to standard measurement error issues in the data (e.g., Kan and Pudney, 2008). The last two entries in this panel are the coefficients obtained on an indicator for a college-graduate parent in two separate regressions: weekly hours with children and annual expenditures on children. As can be seen, the model does a good job in matching these moments.

Labor income inequality is also captured well by the model. Both the Gini coefficient on labor income and top-bottom ratio defined as the ratio of average income between the top 80−95 percentiles and the bottom 5−20 percentiles are similar to the data (both calculated using our PSID sample). The model also does a good job in replicating the share of labor income obtained by esch quintile as well as the capital-output ratio (annualized). The latter is 3.1 in the model, which is in line with the typical estimate of 3 (e.g., Inklaar and Timmer, 2013).

We can also estimate the return to college in the model, another endogenous source of inequality. We find the yearly return to a college education by first calculating, at steady state prices, by how much each agent's lifetime income would change, in net present value terms, by attending vs not-attending college. We then subtract from this figure the cost of a college education p_e and then average over all individuals. This yields an (annualized) return of 8.3%, which is in line with the empirical estimates in the literature of approximately 10% as summarized by Heckman et al. (2006).

Validation: Income Elasticity of Labor Supply

A UBI program may decrease households' labor supply through an income effect. As there is only limited evidence on labor supply from UBI-type policies, we rely on a broader literature to provide evidence on this elasticity. Blundell and MaCurdy (1999) summarize the labor supply literature and report (see Table 1 in their paper) that the median income elasticity of labor supply (based on 22 alternative estimates for men) is -0.07, with the 10^{th} percentile and 90^{th} percentile of these estimates being -0.29 and -0.01.[49]

To estimate the (non-labor) income elasticity of labor supply we transfer income equivalent to $1,000 per year to all households in the economy, keeping all prices fixed at their steady-state values, including taxes (i.e., we do not fund this extra payment as the objective of this simulation is to calculate an elasticity). Given that the empirical estimates in the literature come from environments that vary in the duration of this additional non-labor income, we run the simulations for three alternative durations: one period (or 4 years), five periods (20 years), and for the remainder of life. In all cases, the introduction, but not the duration, of the non-labor income is unexpected. We then compute, for each agent, the

[49] The mapping of this estimate to the model is not perfect as our agents are two-adult households in the data. Another relevant empirical benchmark stems from the evidence on married women. Based on 18 alternative estimates, Blundell and MaCurdy (1999) report that the median income elasticity of labor supply for married women is -0.175, with the 10^{th} percentile and 90^{th} percentile of these estimates being -0.31 and 0.16.

labor supply elasticity as the ratio of the percentage change in hours worked to the percentage change in non-labor income in the first period in which the policy is introduced. Table 5 reports moments of the distribution of labor elasticities obtained from the simulations. The model produces labor elasticities between -0.15 and -0.01, all within the range of estimates reported by Blundell and MaCurdy (1999).

Table 5: Validation: Income Elasticity of Labor Supply in the Model

	Based on $1,000 per year for:		
	One period (4 years)	**Five periods (20 years)**	**Rest of life**
Mean	-0.018	-0.071	-0.084
Median	-0.015	-0.062	-0.084
10^{th} percentile	-0.036	-0.137	-0.147
90^{th} percentile	-0.005	-0.020	-0.025

Note: The income elasticity of labor supply from an extra $1,000 per year of non-labor income given for different durations at fixed prices. See the text for details.

Validation: Cash Transfer Program and Child Skills

Dahl and Lochner (2012) estimate the effect of income on children's development using changes to the Earned Income Tax Credit (EITC) as exogenous sources of income variation. The changes led low-income families to see an increase of up to $2, 100 of disposable income per year. Using an instrumental variables strategy (which uses the change in EITC to predict income based on past income), they estimate the causal effect of income on children's math and reading achievement. Their baseline estimates imply that a $1,000 increase in income raises combined math and reading test scores of children of married parents by 2.8 percent of a standard deviation in the short run.[50]

We introduce a similar policy in the steady-state of the model, by having the government give families an extra $1,000 per year (i.e., an extra $4,000 per period) during the periods that children reside with their parents (i.e., adult periods 8 through 11 or child periods 1 through 4). Since the EITC only affected a relatively small group of families, we keep all prices unchanged, including tax rates, at their original steady-state levels. We assume that the policy lasts one generation and that agents make the same assumption. Thus, we evaluate the policy on the children of the targeted generation.[51]

Figure 4 shows the predicted effect on children's cognitive skills in the simulated model for families with different levels of annual income and, separately, for high-school parents.[52] The model predicts that the cognitive skills of children whose parents' annual income is less $10,000, should increase between 1.3–1.6 percent of a standard deviation. Parents with a high-school education with income in this range should see an increase in their child's cognitive skills of 2.1–2.6 percent of a standard deviation. These

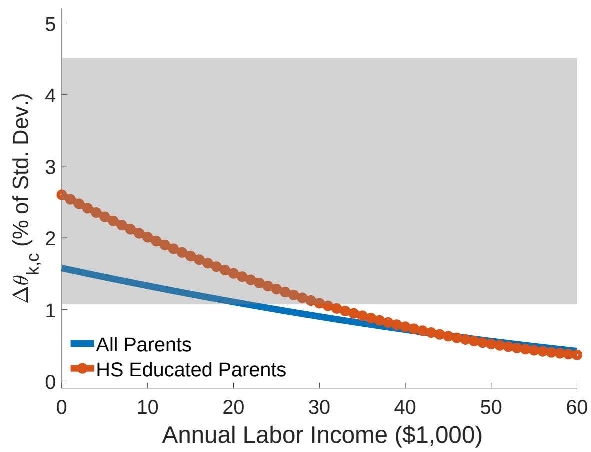
[50] See table 6 in Dahl and Lochner (2017).

[51] This assumption, in addition to being reasonable, simplifies the evaluation since it implies that we do not need to solve a full transition exercise (since children's value functions for a given set of state variables are unchanged).

[52] These estimates are obtained by calculating the effects for many families. Figure 4 reports the average effect by total income, smoothed using a quadratic polynomial on income.

estimates are within the range estimated by Dahl and Lochner (2012), shown in the shaded area in the figure. Note that their study could not estimate how the additional income affects families with higher incomes since the change in EITC mostly impacted households earning below $25,000 a year. It is easy, however, to study this with the model simulations. Reassuringly, as shown in the figure, the effect of the additional income decreases with family income, becoming close to zero around $60,000. We conclude that the model generates results in keeping with Dahl and Lochner (2012), a fact that lends credibility to the model predictions regarding the consequences of a UBI policy.

Figure 4: Validation: Cash Transfer Program and Cognitive Skills



Notes: The change in a child's cognitive skills (as a percentage of a standard deviation) from a transfer of $1000 per year ($4000 per period) to parents, as a function of parent's labor income. The blue (solid) line is for all parents and the red (circles) line is for for high-school-graduate parents. The gray area represents the empirical estimate by Dahl and Lochner (2017) +/- 1 std dev. of 1.7%. See text for details.

4 UBI Policy Evaluation

In this section we introduce the UBI policy as a lump-sum transfer made annually to all individuals once they become adults. We focus our analysis on a particular level of UBI that has been suggested by policy makers and is currently being tested in a short-run small-scale environment by the YC Research group in Oakland, California. We assume that every adult receives an annual transfer of $5,500. In the model, this is equivalent to every adult household (ages 16-79, periods $j = 5$ to $j = 20$) receiving $11,000 per year, equivalent to 17.0% of GDP. This transfer level (in year 2000 dollars) puts a 2-adult household at the poverty line in the absence of any additional income.[53] This policy has been proposed by Democratic presidential candidate Andrew Yang.[54]

We assume that the policy is introduced unexpectedly at the beginning of some period t (denoted by $t = 0$), after individuals have received any shock for that period (e.g., their labor productivity shock,

[53] The poverty line for a 2-adult household, as defined by the U.S. Census, was $11,235 in the year 2000.

[54] It is also the amount evaluated by Hoynes and Rothstein (2019).

taste shock, etc.) but prior to any individual decisions for that period. We examine the dynamic consequences of such a policy, analyzing how it affects the welfare of different cohorts by taking into account intergenerational dynamics as well as general equilibrium effects through prices and taxes.

We explore various alternatives to financing UBI assuming throughout that the budget must be balanced each period.[55] Our baseline policy analysis uses the labor tax parameter λ (which we think of as governing the average labor tax rate) to balance the budget. We also examine a few alternatives: reduced progressivity and a higher consumption tax.

4.1 UBI Baseline Policy: Unchanged τ_y

We assume that the policy is implemented by increasing ω and financed by increasing labor income taxes using λ_t so as to keep the budget balanced each period (see equation 1).[56] The t subscript on λ indicates that this parameter will need to vary endogenously until a new steady state is reached. We refer to this implementation of a UBI policy as the unchanged τ_y case – or the baseline UBI policy. In the figures that follow, the baseline UBI policy is always depicted with blue (solid) lines.

Figure 5 shows the transition effects of the UBI policy on a series of outcomes: i. the average marginal labor-income tax (that is, the derivative with respect to y of the labor tax paid by an agent with labor income y, i.e., $1-\lambda_t\left(1-\tau_y\right)y^{-\tau_y}$), averaged over all agents with $y>0$ starting in the period in which the policy is introduced, $t=0$; ii. the average productivity of each cohort born after the policy is introduced as measured by cognitive skills component in an agent's efficiency units (i.e., by $\psi^e=e^{\lambda^e\log(\theta_c)}$ averaged over the indicated cohort); iii. after-tax inequality as measured by the variance of the log of after-tax income in the cross-section of the population as of the period in which the policy is introduced; and, iv. intergenerational mobility of gross income (as measured by the rank-rank coefficient used by Chetty et al. (2014) multiplied by -1) for each cohort of children born after the policy is introduced. The new steady state is essentially reached by period 30. All the figures show changes relative to the original steady state.

The top left panel of Figure 5 shows that financing the UBI policy requires an initial large increase in average marginal labor-income tax rate of 51% (from 35.9 to 53.6 percent) and that this increases over time to 57% (i.e., to 56.6 percent) above its initial steady state level.[57] The further tax increase is required because the initial decrease in λ decreases agents' incentives to invest in early childhood development and college education. Parental money and time investments are reduced by 41% and 28%, respectively,

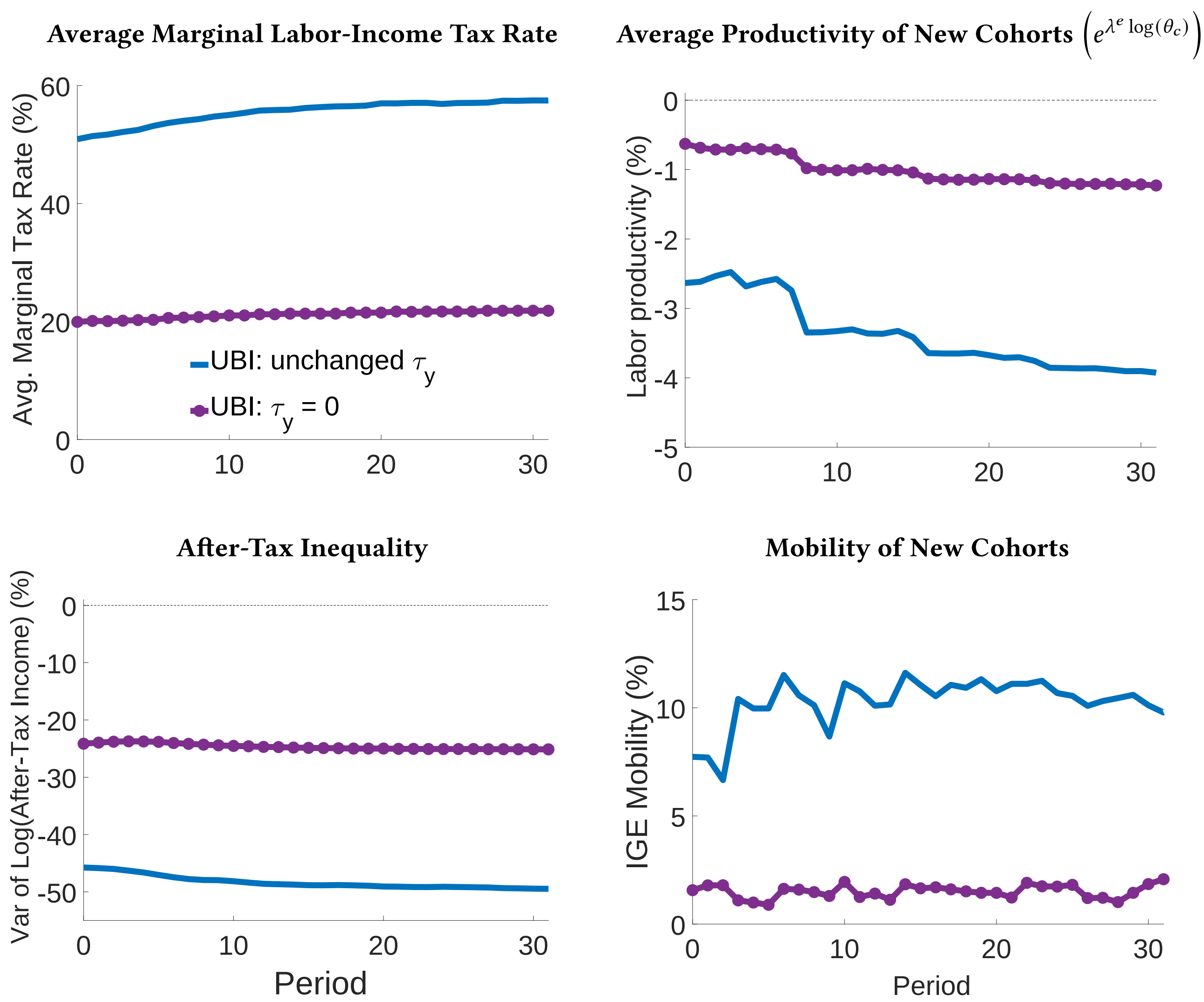
[55] Although we could allow the government to run a deficit, this opens up the question of whether welfare gains could not have been achieved simply by doing so independently of UBI. As we are not conducting an optimal tax exercise, we think that ignoring this option is best.

[56] Recall that the government is assumed to have some constant amount of government expenses G which are the residual in the original steady-state of tax revenue net of transfers ω and retirement benefits. See Appendix A for the expression. G is held constant in all counterfactuals.

[57] We report the change in the marginal tax rate rather than the change in λ_y since the latter has a clearer economic significance.

for the generation born when the UBI policy is introduced, and these reductions become even larger – 50% and 29%, respectively – in the new steady state. The share of agents with a college education falls by 3.0 percentage points for the cohort born when UBI is introduced and by 3.7 percentage points in the new steady state.

Figure 5: Transition Dynamics of UBI: Unchanged τ_y policy vs Replacing Current Progressivity



Notes: The unchanged τ_y UBI policy is in blue (solid) and the alternative UBI policy ($\tau_y = 0$) is in purple (circles). The numbers in the y axes of all figures are in percentage changes from the initial steady state. The 0 in the x axes of the average marginal labor tax and the after-tax inequality figures refers to the period in which the policy is introduced and is measured for the cross-section of agents alive in that period. In the other figures it refers to the first cohort born when the UBI policy is introduced. See text for details.

In terms of inequality, both cross-sectional and intergenerational inequality is reduced. The ratio of parental investment in children from the top 20% of the income distribution relative to the bottom 20% falls: the time ratio goes from 1.6 to 1.1 whereas the money ratio goes from 3.3. to 2.2. As shown in the bottom left panel, after-tax inequality is significantly reduced. The variance of log after-tax income falls by 46% as soon as the policy is introduced. Intergenerational mobility increases: the rank-rank coefficient falls by 7.7% at $t = 0$ and by 8.2% in the new steady state.[58] UBI increases the cutoff at which households receive positive net transfers (ignoring asset and consumption taxation), from $26,822 in the initial state to $32,032 in the new steady state (or 51% of average income in the new steady state). UBI also increases consumption smoothing: the average variance of consumption utility $\left(\frac{c^{1-\gamma_c}}{1-\gamma_c}\right)$ over the life cycle is reduced by 14% at $t = 0$.

It is also of interest to understand how the aggregate variables respond in the steady state.[59] As can be seen in Table 6, GDP falls by 12.9%. 52% of this decrease is due to a fall in the capital stock (of 20.2%) and the remainder to the aggregate efficiency units of labor time supplied (i.e., H as shown in equation 6). For the latter, we can examine how the different components contribute to this. As noted previously, the proportion of college graduates falls by 12.4% (or 3.7 percentage points). The average labor productivity of college-educated individuals falls by 3.7% and that of high-school individuals falls by 1.9%. Hours worked over the life cycle are reduced for both groups: on average by 2.8% for college grads and 7.2% for high school graduates. Figure D2 in the Appendix shows the transition paths of the main aggregate variables (GDP, the capital stock, time worked, and the efficiency units of labor) as well as each newly-adult cohort's college share and labor productivity.

Table 6: UBI: Long-Run Aggregate Effects

	Change from Initial Steady State (%)
GDP	-12.9
Capital	-20.2
Labor (Efficiency Units H)	-9.0
College Share	-12.4
Average Labor Productivity: High-School	-1.9
Average Labor Productivity: College	-3.7
Average Hours Worked: High-School	-7.2
Average Hours Worked: College	-2.8

Notes: Efficiency units of labor H is defined in equation 6. Labor productivity refers to the value of $e^{\lambda^e \log(\theta_c)}$.

Welfare

To summarize, UBI decreases inequality but also skills, education, and capital accumulation. Ultimately, we are interested in understanding how this impacts welfare. We next turn to answering this question.

We can provide a summary measure of welfare under a UBI policy by measuring consumption equiv-

[58] The graph of intergenerational mobility is especially jagged reflecting the fact that this coefficient reflects the incomes of two generations. Take, for example, the cohort born when the policy is introduced (cohort 0). Their parents spent a large part of their lives in an economy without UBI whereas cohorts born further on in the future will have parents (and, eventually and indirectly, grandparents) who are also born in a world with UBI with its attendant effects on skills, education and prices.

[59] Note that as GDP falls, UBI expenses constitute a larger share of the latter, reaching 19.5% of GDP in the new steady state.

alence for various cohorts.[60] The left panel of Figure 6 shows the average welfare gain from the unchanged τ_y UBI policy for different cohorts where the y-axis measures the percent by which – in consumption equivalence units – the UBI policy is preferred to the original steady state. Cohort 0 is the first cohort born when the policy is introduced. Cohorts to the left of zero (that is, until negative 20) are the cohorts who were already alive when the policy was introduced; cohorts to the right of zero are those born after the policy is introduced. For adult cohorts (those to the left of -3) we show average welfare gains by cohort. For all other cohorts, we calculate welfare gains under the veil of ignorance.[61]

As shown in Figure 6, the UBI policy has large negative welfare effects on future cohorts. The tax increases required by the policy reduce investment in skills and education, requiring additional tax increases in the future. Furthermore, the parents of future generations themselves have lower education, which compounds the negative effects on children's skill development as shown by the production function (equation 14). Given the choice between being born in the steady state of the economy without UBI or in that of the UBI economy, an individual would be willing to sacrifice over 9% of consumption to remain in the former.

For generations already alive when the policy is introduced, older cohorts gain on average whereas younger cohorts suffer losses. It should be noted that part of the welfare difference between older and younger adult cohorts is driven by the assumption that children no longer enter their parent's value function once they leave the house, i.e., once they become adults.[62] This assumption, however, was not made for realism but rather to reduce the very large computational burden associated with calculating welfare and transition functions that depend on the state space of parents and children (and even grandchildren for $j \geq 19$), which would increase the state space from four to up to eleven variables (depending on j). Note that this does not mean that parents do not take into account their child's adult welfare when making their skill investment and transfer decisions. It does imply, however, that *unanticipated* policy changes that occur after the child is an adult only impact the parent directly rather than also through their descendants' welfare. This issue does not arise, in any case, for any cohort whose children have not yet been born or for those with children who are not yet adults (i.e., for any cohort $t \leq -10$ as these are of period-age $j \leq 11$ when the policy is introduced).

With the above caveat in mind, as shown in Figure 6, agents who are adults when the policy is introduced (i.e, those of period age $j = 5$ to 20) have a welfare gain of 1.0% in consumption equivalent units.[63]

[60] See Appendix C for details.

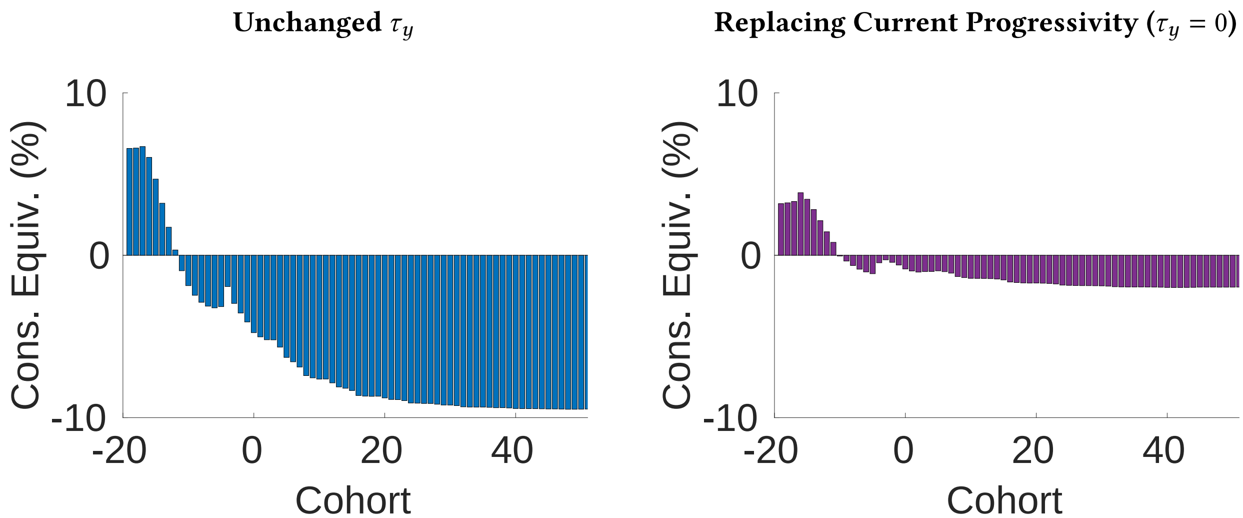
[61] Note that cohorts -1 to -3 are alive when the policy is introduced. To reduce the computational burden, we calculate their welfare change under the veil of ignorance (i.e., under the assumption that the agent obtains a random draw from the equilibrium distribution of the state variables $(\theta, \hat{a}, \kappa)$, which varies by cohort).

[62] This assumption is common in the literature as it helps reduce the computational burden in dynamic models (e.g., Lee and Seshadri, 2019; Abbott et al., Forthcoming) and especially in those that compute welfare changes in OLG models during transitions (e.g., Krueger and Ludwig, 2016).

[63] For agents with adult children, but not with adult grandchildren (i.e., agents of age $12 \leq j \leq 18$), we performed a fuller welfare exercise. We tracked the adult children's state variables and linked them to those of their parents, thereby creating value functions and distributions over the state variables for up to nine state variables. For those generations we found smaller gains (or larger losses) on average than in the baseline welfare calculation. Thus, we present the 1% average welfare gain with that caveat in mind. The pattern of increasing gains with age, however, remained robust. The main takeaway

The winners tend to be older individuals, those who have been hit by an out-of-work shock, and those without a college education.[64] An important conclusion from the welfare analysis (and independent of the aforementioned caveat) is that all generations who are of age $j = 12$ or younger when UBI is introduced suffer losses. These losses are monotonically increasing as of generation -4, the first generation to become adult when the UBI policy is instituted.

Figure 6: Welfare Dynamics of UBI: Unchanged τ_y policy vs Replacing Current Progressivity



Notes: Welfare gain (as measured by consumption equivalence) from the introduction of UBI for different cohorts. Cohort 0 is the cohort born the period in which the policy is introduced. A cohort with a negative number indicates that it was born that (absolute) number of periods prior to the introduction of the policy whereas a positive number indicates a cohort that will be born that number of periods after the policy is introduced. See the text for details.

Table 7: heterogeneity

	Low	**Middle**	**High**
By Wealth (within age)	3.5%	0.6%	-0.5%
By Skills (θ_c)	4.4%	1.0%	-2.3%
By Education	3.0%	–	-3.1%

Notes: This table reports average welfare gains for adult agents at $t = 0$. For wealth and skills, low is below the 25th percentile, middle is between 25th-75th percentiles, high is above 75th percentile of variable.

We can investigate further the heterogeneity in welfare from UBI for households that are adult when the policy is introduced. We can divide, for each age group, households into low (below 25th percentile), middle (25th-75th percentiles), and high (above the 75th percentile), according the their age-adjusted asset holdings. We can also perform the same division by skill level and by education (high school vs college). The consumption equivalent welfare changes from UBI are reported in Table 7. As shown, the

therefore is that to the extent that there are gains for older generations, these are relatively small. The large losses appear for younger generations as noted previously.

[64] See Figure D1 in the Appendix for average welfare gains at $t = 0$ by cohort and education.

winners from UBI are low wealth and low skill adults and those without a college education. Skills and education, more than wealth, are the drivers of the largest differences between winners and losers.

We next turn to exploring the sources of the increasingly large losses over cohorts, especially in the new steady state, and the role played by intergenerational linkages.

4.2 Understanding the Welfare Effects of UBI

In order to understand the welfare consequences of UBI, we perform the following exercises. First, we study mostly steady-state welfare and examine how key variables react to UBI by shutting down various channels (e.g., taxation and GE effects) in order to quantify their contributions. Second, we perform a decomposition of the change in steady-state welfare, allowing us to obtain a lower bound for the contribution of endogenous intergenerational links to this change. Lastly, we delve deeper into the role of intergenerational links by examining the fate of different cohorts over the transition to the new steady state. By studying adjacent cohorts, we can compare the welfare of children whose skills were determined just prior to the introduction of UBI with children whose skills were determined under UBI. Similarly we can compare the last cohort to receive its monetary transfer in the pre-UBI environment to the first cohort whose transfer was determined under UBI. These comparisons allow one to understand how these linkages impact welfare over the transition to the new steady state.

Welfare Analysis: Incentives, Taxation, and General Equilibrium

How does UBI affect welfare? First, UBI provides a floor to how low income can fall, which is especially useful for poorer agents with high marginal utility of consumption. It therefore allows agents to decrease their consumption variance and permits them to invest more in their children, if they so wish. We will refer to this as effect (i). Effect (ii), on the other hand, arises from the negative incentive effect to invest in children if the latter will obtain a significant transfer from the government; having a higher skill level becomes less important. In addition to this, even for the same level of skills, the child itself may find college less attractive given that they will be receiving UBI. A third effect arises from the fact that taxes need to be adjusted to balance the budget. Finally, by modifying skill formation and education incentives, UBI may lead to GE changes regarding wages and interest rates (effect (iv)).

In order to quantify the importance of these channels, Table 8 reports the results from several exercises that shed light on their significance. The first row reports the effects of UBI in what we call "the short run." In this exercise, only one cohort obtains the UBI benefit (which starts at age $j = 5$). This cohort understands that only they will be provided with the UBI benefit and thus over time the economy will transition back to its original steady state. Throughout this exercise, prices and taxes are maintained at their original steady-state level. In this sense, it resembles the validation exercise conducted in section 3.2 that examined the effects on children's skills of a cash transfer. As can be seen from the table, this cohort reacts by increasing investments in children's skill formation substantially (both time and money) as well as transfers. This response results in an increase in the children's cohort average labor productivity (in the sense described previously) of 1.4 pp, an increase in the proportion of children who become college graduates by 2 pp (which is a 6.8 percent increase over its mean), and an overall increase in the welfare of the cohort that received UBI (as measured in consumption equivalent terms) of 19.2%. This increase is not surprising: the cohort is being bestowed a free gift. They share the benefits of this gift with their descendants, by providing them with greater skills and transfers which, over time, return to their original steady-state levels.[65]

The second row turns to the longer-run consequences and asks what would be the welfare effect if *all* cohorts were given this gift. It too abstracts both from any need to fund UBI and from any general equilibrium consequences on prices arising from changes in agents' decisions. The numbers reported here, including those of welfare, are from the new steady state obtained under these premises. Effect (ii) now comes into play. Investment in children and parental transfers fall substantially, as does average labor productivity and, especially, the proportion of college graduates which falls by 26%. As all cohorts receive the UBI benefit, parents' desire to invest in their child's skills falls as does the latter's desire to attend college. The incentive to save also decreases substantially as indicated by the 14.5% fall in the capital stock. Welfare nonetheless necessarily increases as the benefits now accrue to all and, since these are free, concavity implies that all generations benefit as parents also want future descendants to be better off.

The third row maintains the universality of the UBI benefits but now requires them to be funded via changes in the labor-tax parameter λ. Prices, however, are kept at the original steady-state value. As can be seen, relative to the non-taxation scenario, there is an even larger drop in both money investments in children's skills as well as transfers to children. This results in a fall of average labor productivity by over 5% and the proportion who graduate from college by a large proportion – over 9 pp. The capital stock's fall is much larger now: 42%. This row also shows that taking into account the increased taxes required to fund UBI is responsible for all of the long-run welfare losses, in fact exceeding it by 2.8 percentage points. To differentiate between the incentive effects of higher taxes and those of UBI, the last line of the table (LR-PE Taxes without UBI) confronts agents with the tax rate from the steady state of line 3 but does not give them the UBI benefit. The new steady state reached in this environment sees a smaller decrease in time and money investments in child skills as well as in transfers to the latter. Consequently the fall in college share and labor productivity is significantly smaller, as is the fall in the capital stock. This allows us to conclude that a significant share of the effects of UBI with taxation (but no price changes) stem from the combination of taxes and UBI.

Finally, the 4th row reports the full steady-state effects of the UBI policy by incorporating the general equilibrium price changes in addition to the tax changes. The general equilibrium effects help mitigate the negative effects of taxes. The return to college increases due to the fall in the proportion of college

[65] We leave the effect on the capital stock blank as it depends when the latter is measured. Over time, capital returns to its original steady-state value.

graduates, leading more agents to attend college and thus causing this fraction to fall by 12.4% (3.7 pp) rather than the 31.3% (9.4 pp) of the preceding exercise. The overall steady-state welfare loss is correspondingly smaller.

Table 8: UBI: From Short-Run PE to Long-Run GE

Alternative Exercises			**Change from Initial Steady State (%)**						
Long Run	**Budget Balanced**	**GE**	**Time** t	**Money** m	**Parental Transfers**	**Labor Prod.**	**College**	**Capital**	**Cons. Equiv.**
No	No	No	7.3	21.8	52.2	1.4	6.8	–	19.2
Yes	No	No	-26.7	-17.8	-37.4	-2.9	-26.0	-14.5	24.1
Yes	Yes	No	-29.4	-49.7	-66.1	-5.2	-31.3	-42.0	-11.9
Yes	Yes	Yes	**-29.3**	**-49.8**	**-33.0**	**-3.9**	**-12.4**	**-20.2**	**-9.1**
LR-PE Taxes (without UBI)			-13.6	-36.7	-34.0	-1.8	-0.7	-30.0	-43.2

Notes: The column "Long Run" indicates whether the variables, including welfare measured in consumption equivalence units, are those from the stationary equilibrium obtained under the experiment conducted in the text. Labor productivity refers to the value of $e^{\lambda^e \log(\theta_c)}$. LR-PE Taxes (without UBI) refers to the steady state λ from column 3 but without the accompanying UBI grant.

UBI and Intergenerational Linkages: A Steady-State Decomposition

To understand the sources of steady-state welfare losses from UBI and, in particular, the role of intergenerational linkages, the following decomposition is instructive. Changes in welfare arise, necessarily, from two sources: (i) changes in the value of an agent at each state $V_{j=5}(a, \theta, \varepsilon)$, and (ii) changes in the distribution over those states $\mu_{j=5}(a, \theta, \varepsilon)$.[66] The changed distribution of $\mu_{j=5}$ is the result of endogenous parental decisions of skill investment and monetary transfers, i.e., of the intergenerational links that we highlight in the model. Thus, one way to gauge the quantitative importance of these is to recalculate welfare gains by keeping $V_{j=5}$ constant at their original steady-state values (i.e., from the economy without UBI) but changing the distribution $\mu_{j=5}$ to the one in the steady-state of the economy with UBI, $\mu'_{j=5}$. Performing this calculation yields a welfare loss of -3.8%, i.e., 42% of the total losses of 9.1 percent. It is important to note that this calculation yields a *lower bound* for the contribution of intergenerational links to the change in steady-state welfare; changes in $V_{j=5}$ are in part due to the higher taxes required solely as a result of the lower skills and education.[67]

[66] The $j = 5$ in the value function serves as a reminder that this is the period-age when agents become adults.

[67] We can alternatively keep constant the original distribution $\mu_{j=5}$ and change only the original steady-state $V_{j=5}$ to the ones obtained in the steady state of the economy with UBI: $V'_{j=5}$. In this alternative exercise we obtain welfare losses of -5.7%, i.e., 62% of the total losses, pointing to the importance of the welfare losses coming from taxation and GE effects (which again, reflect in part the intergenerational links).

UBI and Intergenerational Linkages: Young Cohorts During the Transition

A complementary exercise can deepen our understanding of the role of intergenerational linkages. Table 9 reports the change in key variables for various cohorts. The cohort indicated by a zero denotes the cohort born when the UBI policy is instituted. This is the first generation in which all the individual state variables are determined within the new UBI environment. Cohort -3 was born 3 periods before the UBI policy was instituted at $t = 0$. Thus its skills (θ) were already determined prior to $t = 0$ but not parental transfers nor college decisions. Cohort -4 and -5 were born 4 and 5 periods before $t = 0$ and thus have pre-determined state variables ($\theta, \hat{a}$) and ($\theta, \hat{a}, e$), respectively, at $t = 0$. Thus cohort -4 has yet to decide whether to become college educated whereas cohort -5 is the last cohort to have all its state variables determined prior to the imposition of the UBI policy. How each cohort fares allows us to have an understanding, albeit imperfect, of the importance of intergenerational links in the transition to the new steady state.[68] The column on the far right denoted "steady state" indicates that all variables are for individuals born in the new steady state of the economy with UBI. Comparison with the values of the variables in that column give an idea of how much of the transition has happened in the first few periods after the policy is introduced.

Each variable is calculated under three different scenarios, similar in nature to rows 2-4 of Table 8. The first row abstracts both from the change in the tax rate required by UBI and from general equilibrium effects, the second introduces the necessary taxes, whereas the third allows, in addition, general equilibrium effects. In each scenario, all variables adjust endogenously and, unlike the mostly steady-state perspective adopted in Table 8, the changes that are reported are the average for the indicated cohort.

As can be seen in Table 9, the large decrease in time and money invested in child skills is suffered already by the first cohort that can be affected by UBI – cohort 0 – almost as much as for cohorts born in the new steady state. As in Table 8, the fall in money investment in childhood skills becomes substantially larger once we impose budget balance. Parental transfers decrease significantly, not only for cohort 0, but also for cohort -3. It is larger, however, for cohort 0, even without requiring budget balance, indicating that parents are on average less inclined to subsidize their child's college education after investing less in their skill formation. Indeed as can be seen in the college panel, a smaller proportion of children obtain a college education from cohort 0 than cohort -3 under all scenarios. It follows that the fall in labor productivity is larger for cohort 0 than cohort -3.

Turning next to cohort -4, a comparison of the first and second row in the college panel shows that the 16% decrease in the college share is reduced to a 12.6% fall (taxation) and then to a 12.1% (taxes and GE) drop once UBI is no longer a free gift. It is interesting to note, however, comparing cohorts -3 and -4 (who do not differ in their skills but receive very different parental transfers), that the reduction in the college share is actually larger for cohort -4. This is due in part to the fact that the younger cohort (-3) has a higher marginal return to consumption as it is poorer since the profile of taxes it will face over its

[68] Imperfect because each cohort lives a different fraction of its life in the new environment which is also changing as the economy transitions to the new steady state.

life time is higher (for one period) and because parental transfers are lower.

Table 9: UBI: Outcomes for Various Cohorts

Alternative Exercises		**Cohort**				
Budget Balanced	**GE**	**-5 (Fixed $\theta, \hat{a}, e$)**	**-4 (Fixed $\theta, \hat{a}$)**	**-3 (Fixed θ)**	**0**	**Steady State**
		Time Investment Received (%)				
No	No	0.0	0.0	0.0	-24.2	-26.7
Yes	No	0.0	0.0	0.0	-26.8	-29.4
Yes	Yes	**0.0**	**0.0**	**0.0**	**-28.0**	**-29.3**
		Money Investment Received (%)				
No	No	0.0	0.0	0.0	-11.2	-17.8
Yes	No	0.0	0.0	0.0	-38.7	-49.7
Yes	Yes	**0.0**	**0.0**	**0.0**	**-41.1**	**-49.8**
		Parental Transfers Received (%)				
No	No	0.0	0.0	-15.5	-18.3	-37.4
Yes	No	0.0	0.0	-23.6	-32.0	-66.1
Yes	Yes	**0.0**	**0.0**	**-17.9**	**-21.8**	**-33.0**
		College (%)				
No	No	0.0	-16.0	-16.6	-18.0	-26.0
Yes	No	0.0	-12.6	-12.3	-18.5	-31.3
Yes	Yes	**0.0**	**-12.1**	**-11.3**	**-15.4**	**-12.4**
		Labor Productivity (%)				
No	No	0.0	-1.2	-1.2	-1.7	-2.9
Yes	No	0.0	-0.9	-0.8	-2.7	-5.2
Yes	Yes	**0.0**	**-0.8**	**-0.8**	**-2.6**	**-3.9**
		Consumption Equivalence (%)				
No	No	26.2	27.4	26.4	26.0	24.1
Yes	No	-3.2	-2.0	-3.3	-5.1	-11.9
Yes	Yes	**-3.2**	**-1.9**	**-3.0**	**-4.8**	**-9.1**

Notes: All the numbers reported are in percentage change relative to a cohort born in the initial steady state. Cohort 0 is the cohort born the period in which the UBI policy is introduced. A cohort with a negative number indicates that it was born that (absolute) number of periods prior to the introduction of the policy whereas "Steady State" refers to the cohort born in the new steady state after the policy is introduced. Labor productivity refers to the value of $e^{\lambda^e \log(\theta_c)}$.

Lastly, turning to the welfare consequences, note that neither the gains nor losses are monotonic over these cohorts: cohort -4 gains the most when UBI is a pure gift (row 1) and loses the least once the required taxes are imposed (rows 2 and 3). This is not surprising as this cohort does not suffer the losses in skill investment and/or parental transfer of cohorts -3, 0 and steady state, and furthermore it can optimize over its college decision with the same state variables as cohort -5 whose college decision is not optimal given the UBI policy.

The differences in welfare losses across cohorts -4, -3 and 0 highlight the importance of intergenerational linkages. For cohort -4, parents cannot reoptimize and change their skill investment and monetary transfer when faced with the UBI policy. This benefits that cohort: its welfare losses are 60% smaller (-1.9 vs -4.8) than for cohort 0 – the cohort for which parents are able to fully readjust skill investment and transfers. For the intermediate cohort that has fixed skills but for which parental transfers can be reoptimized (i.e., cohort -3), losses are 38% smaller than for cohort 0. Thus, roughly a third of welfare effects stemming from interegenerational linkages are due to parental transfers with the remaining part driven by parental investments in skills.[69]

4.3 Alternative Implementations of UBI

In this section we examine alternative ways to implement UBI. We first consider the case in which the UBI reform replaces the current progressive tax rate on labor income with a linear schedule. This is a way to study a reasonable alternative scenario in which UBI replaces some current spending on poorer individuals. We next study how the baseline results would be modified if consumption taxes were used instead of labor income taxes. Third, we evaluate the robustness of the baseline UBI results to greater wage uncertainty than what we estimated. Finally, similar in spirit to the UBI implementation with linear taxation, we study the case in which UBI eliminates the current social programs captured by ω.

UBI and Linear Labor Income Taxation

In the preceding analysis, UBI is modeled as an additional source of income redistribution beyond that already provided by the current tax and transfer system. This system includes social programs and benefits primarily targeted to poorer households as well as redistribution (e.g., Medicaid, food stamps, AFDC, and EITC). Given that the UBI policy would ensure that households did not fall below the poverty level, a reasonable conjecture is that some of these programs would be cut back or even eliminated.

Reducing the importance of these social programs could be interpreted, through the lens of the tax function, as a reduction of the tax progressivity parameter τ_y since it would reduce the tax benefits of low-income households. Although the degree to which these programs would be reduced is unclear, one way to explore this question is by evaluating the extreme case of a linear labor income tax. Thus, in this section we model UBI as an increase in ω as before but simultaneously set $\tau_y = 0$. The level of non-modeled government expenditures G remains unchanged, hence the labor tax parameter λ must adjust to balance the budget.

[69] This is a rough calculation as these cohorts live in slightly different environments as they are separated by one or more periods. The forces from GE and taxation effects go in opposite directions, however. While the slow increase in taxes over time increase the welfare losses for younger cohorts, the slow increase in college wages tends to reduce them.

Given that the policy experiment essentially consists of two parts (i) a change in the marginal tax system to a linear tax (i.e., τ_y is set to zero) and then (ii) an increase in ω by the amount of the UBI transfer, it is useful to first ask how much each contributes to the change that is required in λ. If the change were restricted to setting $\tau_y = 0$, λ would decrease from its original value of .79 to .77 in the first period, eventually increasing to .78 in the new steady state.[70] In terms of the average marginal labor-income tax rate, this would drop by 37.8% (13.6pp) in the first period and by 40.2% (14.4pp) in the new steady state.

Next, the purple (circled) lines of Figure 5 show the effects of requiring the new tax system to fund the increase in ω required by UBI. As shown in the upper left-hand figure, this policy requires a significantly smaller increase in the average marginal labor-income tax rate (which is now the same for all labor income, i.e., it is $(1 - \lambda)$ given that $\tau_y = 0$) than when τ_y was left unchanged. When the policy is introduced, the average labor-income tax rate requires an immediate 20% increase, in contrast with the 51% required in the preceding case. Moreover, in contrast with the original UBI program, this alternative requires smaller further increases in that tax rate. The linear labor tax policy, furthermore, reduces the disincentive for higher-income agents to invest in skills and education relative to the baseline (unchanged τ_y) case. Parental money and time investments m are reduced by 21% and 12%, respectively, in the new steady state — less than half the reduction obtained under the original UBI policy. The percent of agents with a college education falls by 0.7 percentage points (or 2.4%) in the new steady state, about one-fifth of the reduction obtained under the UBI policy with an unchanged τ_y.

Intergenerational mobility does not increase as much as under the previous UBI policy. Furthermore, as shown in the bottom left-hand side of Figure 5, the counterpart of the linear tax rate UBI policy is that the variance of the log of post-tax income is reduced by far less than in the unchanged τ_y policy. This is a direct consequence of the lack of progressivity in the marginal labor tax rate.

Lastly, the right-hand side of Figure 6 shows that this alternative way to finance UBI leads to relatively similar average welfare gains for generations who are alive when the policy is introduced as the benchmark case.[71] Older agents are better off but younger ones are worse off, leading to a similar average gain. The gains for the older individuals, as in the prior case, come from receiving a larger payment in retirement. Young college-educated households and, particularly, future cohorts prefer this alternative policy to the original UBI policy. This is because young high-skilled workers benefit from the lack of progressive marginal tax rates on labor income and because future cohorts see a smaller reduction in parental investments in their skills. Parental skills, of course, are also higher and both are inputs into skill formation and education outcomes. It is worth emphasizing, however, that all future generations prefer not to have a UBI policy. Individuals would be willing to sacrifice 1.9% of consumption to be born (under the veil of ignorance) in the no UBI steady-state environment than to be born in the steady state

[70] Recall that a decrease in λ is an increase in the labor tax (for a fixed τ_y).

[71] The cutoff household labor income at which households receive a net transfer (ignoring capital and consumption taxation) increases from $26,822 in the initial steady state to $30,615 in the new steady state (or 44% of the new steady state average household income).

of the alternative UBI policy.

UBI and Consumption Taxation

The US stands out among OECD countries for its low reliance on consumption taxation.[72] An alternative to increased taxation of labor income would be to increase the taxation of consumption to finance UBI. We now briefly explore the consequences of pursuing this alternative source of additional revenue.

A consumption tax funded UBI policy requires an increase in the consumption tax of 24 percentage points right away. Over time, a further increase is needed bring the steady-state increase to 25 percentage points. The welfare consequences of this UBI policy differ radically from those of studied previously. As can be seen in Figure 7, the older cohorts are now the ones who lose, whereas those who are young when the policy is instituted tend to gain. Cohorts born in the new steady state also gain, although these gains are relatively small (0.5% in consumption equivalence terms).[73] Overall, individuals who were adults at the time that UBI is introduced suffer a 1.0% decrease in their consumption equivalent welfare on average. These losses are born by older individuals who are either retired or closer to their retirement age and thus bear the brunt of the consumption tax as their accumulated wealth needs to be consumed. College-educated workers' losses are larger as the UBI grant is a smaller compensation proportionally for the higher tax on their consumption; this is true for young college workers as well. The winners among younger workers are those with a high-school education.[74]

To gain a better understanding of the welfare results, it is useful to perform an alternative exercise. Suppose that *prior* to any UBI policy, we increase the consumption tax by the full 25pp that would be required under the consumption-tax-financed UBI policy, allowing the labor income tax λ to adjust so that the budget remains balanced. That is, we are simply changing the tax instrument mix without introducing UBI, so as to keep the government budget balanced. The consequences of this change are large welfare losses among those who are adults when this change is introduced (-2.8% in consumption equivalence units) and large steady-state gains of 5.9%, echoing the findings in favor of consumption taxation in the literature (e.g., Coleman, 2000; Correia, 2010). This indicates that the gains from a consumption-tax-financed UBI are due to the change in tax system — to a greater reliance on consumption as opposed to labor taxation — rather than to the insurance or credit-constraint changing properties of the UBI payment.[75]

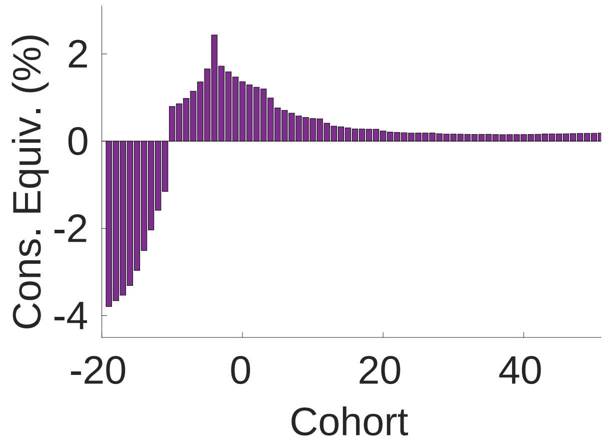
[72] In 2018, taxes on goods and services accounted for 17.6% of tax revenue whereas it accounts for 32.1% on average among other OECD countries (Enache, 2020).

[73] Luduvice (2019) also finds that a UBI policy (of a similar magnitude to the one here) financed by consumption taxes leads to long-run welfare gains. Our evaluation of UBI financed with labor income taxes vs consumption taxes suggest that this is likely due to the larger role played by consumption taxation rather than to UBI itself.

[74] See Appendix Figure D3.

[75] Indeed, eliminating labor taxes altogether and relying instead on consumption taxation without UBI (i.e., setting $\lambda = 1$, $\tau_y = 0$, and increasing τ_c to balance the budget), yields large welfare losses among the current adults (of -5.2%) and large steady-state welfare gains (of 8.4%).

Figure 7: Welfare Dynamics of UBI: Financed with Consumption Tax



Notes: Welfare gain (as measured by consumption equivalence) from the introduction of UBI for different cohorts. For the figure on the left, cohort 0 is the cohort born the period in which the policy is introduced. A cohort with a negative number indicates that it was born that (absolute) number of periods prior to the introduction of the policy whereas a positive number indicates a cohort that will be born that number of periods after the policy is introduced.

UBI with increased wage shocks variance

The baseline model essentially assumes complete markets within a 4-year-long period and, by doing so, may diminish the welfare consequences of a UBI policy. To evaluate the importance of this assumption, we double the variance of the wage shocks, σ_z^e, and examine how this affects the welfare gains from UBI.

The first column of Table 10 reproduces the results from introducing UBI keeping τ_y unchanged. The second column shows the results of doubling the variance of the wage shocks (leaving all other parameter values unchanged). Welfare reacts in a similar pattern as before, but with larger gains on average for adults alive when the policy introduced and smaller losses in the new steady state.

Table 10: UBI: Robustness

	Baseline	**Double σ_z^e**	**UBI substitutes for initial ω**
Avg. welfare gains for adults at $t = 0$	1.0%	2.6%	1.8%
Welfare gains in steady state	-9.1%	-7.7%	-7.6%

Notes: $t = 0$ refers to the period in which the policy is introduced. Welfare gains are in percentage change in consumption equivalent units.

UBI substitutes for initial ω

An earlier exercise studied a UBI policy in which the current degree of progressivity of the taxation of labor income was replaced by a linear tax, i.e., $\tau_y = 0$. An alternative way to model the idea that

UBI could replace other forms of transfers to lower-income households is to instead have it replace the original level of transfers, i.e., ω. We study this alternative by assuming that the net increase in UBI per household per year is $8,600, i.e., the $11,000 (baseline UBI value) minus $2,400 (the estimated value of ω). The third column of Table 10 shows that the welfare effects are similar to those obtained under the original UBI policy.

5 Job Destruction and UBI

As shown, UBI has different welfare consequences in the short versus the long run, with generations that are young when UBI is introduced bearing welfare losses and, furthermore, with these losses increasing over time. Is this conclusion robust to a more difficult economic environment in which jobs are destroyed/lost more frequently? We now turn to this question, motivated by current fears of the future consequences of robotization and automation.

5.1 Higher Frequency of Bad Shocks (Automation)

A major concern regarding greater robotization/automation is that it will considerably reduce the number of jobs available by making certain occupations obsolete. From this perspective, it is argued by some that a UBI policy would help provide the basic needs of individuals who were negatively impacted.[76] Although the present model is not designed to understand automation, it is able to reflect an important concern in a simple fashion by viewing the consequences of this accelerated technological change as an increase in the proportion of workers who receive an out-of-work shock.[77]

The baseline (steady state) model implies that, conditional upon currently working, individuals who are of period age $j = 5$ to period age $j = 10$ inclusive experience an out-of-work shock with probability 3.3% over the next 7 periods (i.e., 3.3% of the individuals who are between 16-20 and 36-40 years old and working will get hit by an out-of-work shock over the next 28 years as they age and turn 44-48 to 64-68 years old). McKinsey (2017) and OECD (2019) predict the share of current jobs lost as a result of automation could be between 5% and 15% but numbers even closer to 25 or 30% have been suggested (Frey and Osborne, 2017). Most of the empirical evidence also suggests that the occupations of less-educated individuals are more likely to be affected. We introduce the higher rate of automation by increasing each age-dependent probability of entering the out-of-work state (as shown by the left panel of Figure 2) by a common education-specific factor in such a way as to match estimates on the share of current jobs that would be lost over 30 years. Following the estimates of McKinsey (2017), we assume that the probability that a college graduate loses their job is 58% lower than the one for a high-

[76] This has been suggested, among others, by Elon Musk, Richard Branson, and Mark Zuckerberg (see, e.g., Clifford, 2018)

[77] Acemoglu and Restrepo (2020) show that commuting zones most exposed to industrial robots saw decreases in employment and wages.

school graduate.[78] We leave unchanged the probability of a worker transitioning from out-of-work to employment as how automation affects job creation is unclear.

Note that, ceteris paribus, a higher frequency of out-of-work shocks for high-school educated workers implies a lower college premium: high-school workers essentially become scarcer (see equation 7). As this is simply a consequence of using a model in which unemployed workers do not compete for jobs and, furthermore, contradicts most predictions regarding the returns to less-skilled labor, we adjust the weight s of college vs non-college work in the aggregate production function (6) such that, keeping the aggregate capital stock fixed at its initial steady-state value and allowing the aggregate labor supply (H_0 and H_1) to adjust only due to the exogenous increase in the probability of being out-of-work (i.e., no endogenous changes in skills, education or labor supply), the unit wage of high-school educated workers, w_0, is unchanged.[79] Lastly, as there is no reason to believe that automation would reduce GDP (which would otherwise fall, ceteris paribus, simply as a result of greater out-of-work shocks), we increase total factor productivity in (6) such that, after adjusting s, GDP remains constant at the original capital stock and aggregate labor (with the latter adjusted mechanically for the higher probability of being out of work).[80]

More rigorously, let H_0^*, H_1^*, and K^* be the initial steady-state values of high-school labor, college labor, and capital, respectively. Let $\hat{H}_0$ and $\hat{H}_1$ be the corresponding values if the only adjustment were in the (exogenous) increase in the probability of being out-of-work (i.e., keeping unchanged skills, education, and labor supplied conditional on working). To keep the return to an efficiency unit of high-school workers unchanged, we find $\hat{s}$ such that $w_0\left(\hat{H}_0, \hat{H}_1, K^*|\hat{s}\right) = w_0\left(H_0^*, H_1^*, K^*|s\right)$, as defined by equation (7). Let $\hat{H}(\hat{s})$ be the resulting aggregate labor supply using $\hat{s}$. To keep output unchanged, we then increase total factor productivity, (previously normalized to equal 1), to $\hat{A}$ such that $\hat{A}\left(K^*\right)^{\alpha}\left(\hat{H}(\hat{s})\right)^{1-\alpha} = A\left(K^*\right)^{\alpha}\left(H^*\right)^{1-\alpha}$.

Table 11 reports some key aggregate variable values for the new steady state reached under different occupation/job destruction rates, ranging from 5% to 30%, assuming throughout that the change in the destruction rate was unforeseen at $t = 0$. These are all indicated as the percentage change relative to the steady-state of the benchmark model. Note that GDP does not react in a monotonic fashion: it first falls and then increases. The latter is a consequence of an endogenously growing capital stock as agents increase savings to better protect themselves against the increased income risk, an endogenously larger share of college educated workers as the latter face lower risk making college more attractive, an endogenously higher number of hours worked conditional upon working (as can be seen by the row that excludes the out-of-work agents), and an exogenous change in TFP stemming from the procedure

[78] Hence, the probability of being out of work in period j if an individual with education e was working in period $j-1$ goes from x_j^e to $x_j^e(1+q^e)$ for all working periods, $e \in \{0, 1\}$.

[79] This strategy implies that college workers have a more sizable role in the economy which is in line with the prediction that the new jobs created by automation will require more skills (e.g., McKinsey, 2017; Frey and Osborne, 2017; OECD, 2019).

[80] A full model of automation would endogenize the latter and specify who gets the returns associated with the technological change.

described previously.

Table 11: Automation: Long-Run Aggregate Effects

Jobs Destroyed	5%	10%	15%	20%	25%	30%
	Change from Initial Steady State (%)					
GDP	0.0	-0.1	0.0	0.7	1.3	2.0
Capital	1.9	6.0	9.7	13.8	17.4	20.8
Labor (Efficiency Units H)	-1.5	-5.5	-8.7	-11.4	-13.9	-16.3
College Share	0.9	4.5	8.9	12.9	17.3	20.9
Average Labor Productivity: High-School	0.0	0.1	0.1	0.2	0.3	0.6
Average Labor Productivity: College	0.0	-0.1	-0.0	-0.1	-0.5	-0.7
Average Hours Worked: High-School	-1.6	-5.8	-9.4	-11.8	-14.1	-16.3
Average Hours Worked: College	-0.8	-3.2	-5.5	-7.8	-9.9	-11.7
Average Hours Worked: All, Excl. Out of Work	0.2	0.7	1.0	1.1	1.3	1.4
Total Factor Productivity $\hat{A}$	0.4	1.8	3.1	4.6	6.2	7.9
High School Weight in Aggregate Labor $\hat{s}$	-0.3	-1.2	-2.1	-2.9	-3.9	-4.7
Interest Rate r	-3.7	-12.7	-20.4	-25.9	-31.1	-36.8
High-School Wage w_0	1.3	4.6	7.9	10.5	13.1	16.2
College Wage w_1	0.4	1.8	2.9	4.2	5.5	7.1
Average Marginal Labor-Income Tax Rate	0.7	2.6	4.2	5.1	5.9	6.8
Welfare in Steady State	-0.68	-1.75	-1.92	-1.42	-0.69	0.01
Welfare for Adults at $t = 0$	-1.04	-3.32	-5.07	-6.08	-6.92	-7.55

Notes: Efficiency units of labor H is defined in equation 6. Labor productivity refers to the value of $e^{\lambda^e \log(\theta_c)}$. *Adults at* $t = 0$ *refers to agents who are adults when the policy is introduced; steady state refers to agents born in the new steady state with welfare evaluated behind the veil of ignorance.*

Agents who are adults when the job destruction rate increases are on average worse off the greater is the "out-of-work" shock. Not only are they facing a higher job-destruction rate, but also a higher marginal labor income tax rate as the budget must still be balanced in every period. Welfare in the steady state reacts non-monotonically: there is a small welfare gain with the largest shock. This is due to the fact that agents born in the new steady state will not pay the price of the buildup of the capital stock nor of the greater share of college-educated parents.

5.2 UBI In A Riskier Economy

We next revisit how the introduction of UBI affects welfare under these changed environments. The policy is introduced at the same time that the economy becomes riskier — in period $t = 0$ — and thus the adults in this economy would already have their skills set and, for all those other than the agents of period-age j=5 (i.e., 16-20 year olds), their college decision made. The first column of Table 12 labeled "Adults at $t = 0$" reports, in consumption equivalence units, the average percentage of consumption adults would be willing to sacrifice in order to have the baseline UBI policy introduced. The second column performs a similar consumption equivalence exercise, but this time for cohorts born in the new steady state of the economy with the UBI policy (under the veil of ignorance). The welfare comparison is always to the riskier economy without UBI.

Table 12: Automation: UBI Welfare

Jobs Destroyed	Welfare Gains: Cons. Equiv. (%) Adults at $t = 0$	Steady State
Baseline = 3.3%	1.01	-9.13
5.0%	1.28	-9.22
10.0%	1.66	-10.02
15.0%	1.80	-11.15
20.0%	1.97	-11.76
25.0%	2.12	-12.55
30.0%	2.25	-13.08

Notes: This table shows the welfare effects of the unchanged τ_y UBI policy. Adults at $t = 0$ refers to agents who are adults when the policy is introduced; steady state refers to agents born in the new steady state with welfare evaluated behind the veil of ignorance.

As can be seen by contrasting the two columns, a riskier economy has different implications for current adults vs future cohorts. The cohorts that are adults when the baseline UBI policy is introduced are the ones least able to adjust to the increased risk, both in terms of education choices and asset accumulation. Thus, higher levels of automation increases the value of UBI for them. Future cohorts are also more likely to be out of work, but the losses from UBI are larger since the capital stock has fallen during the transition, as have investment in child skills and the share of agents that obtain a college education. The average marginal labor-income tax rate required to fund UBI is therefore increasing in the share of jobs destroyed, thus also increasing the welfare losses to the cohorts born in the new steady state.[81] Altogether, the results above suggest that UBI may be a useful transitional policy to help older individuals who are not prepared to live in an environment with increased risk of job loss. A permanent universal income system, however, would still have large negative welfare implications in the longer run, even with a riskier environment.

6 Conclusion

The objective of this paper is to evaluate a UBI policy in a framework able to capture the fundamental features of its potential costs and benefits. We develop an overlapping generations, general equilibrium, life-cycle model with imperfect capital markets and endogenous choices of labor supply, saving, education, and investment in the skills of one's children. Agents are subject to various sources of uncertainty including income and "out-of-work" shocks. The steady state of the model is estimated to match household level data with a tax function that is parameterized to be a good fit for the US economy.

[81] See Appendix Table D2 for more details on the aggregate effects of UBI together with automation.

We introduce a UBI policy that provides each household with $11,000 per year, financed by additional taxes. This policy has different implications in the short versus the long run. Whereas older agents have either small gains or losses (with the oldest cohorts and low skilled, non-college educated agents gaining the most), younger cohorts on average suffer significant welfare losses. These losses are even larger for future cohorts not yet born. Evaluating welfare behind the veil of ignorance, individuals would strongly prefer to live in the steady state of the economy without the UBI policy than in the corresponding one of the economy with UBI: they would be willing to sacrifice over 9% of consumption to do so. We show that endogenous intergenerational linkages play a significant role in this welfare loss: parents substantially reduce the time and money investments in their child's skills and greatly decrease their transfers to them. This leads to a changed distribution over the state space once agents become adult, contributing over 42% of the fall in steady-state welfare. In the transition to the new steady state, the last cohort to have its skills and transfers determined in the old environment loses 60% less than the first cohort to have its skills and transfers determined in the new environment.

Motivated by currents fears of automation/robotization, we also examine how increased job destruction affects the desirability of UBI. We model automation as an increase in the probability of suffering an out-of-work shock, using estimates from the literature on the fraction of current jobs/occupations predicted to become obsolete. We find that UBI becomes more attractive on average to adult cohorts that are alive when the policy is introduced, with its desirability increasing in the level of automation. The welfare loss in the steady state, however, remains sizable and increases in absolute value the greater the riskiness of the environment.

We conclude with a remark about the current situation of a pandemic-induced historically-high "out-of-work" shock that, once again, has disproportionately affected individuals with less education. The call for UBI has resurfaced, becoming more popular both in the US and in Europe.[82] While strong income support measures for all those in these circumstances and the creation of a permanent machinery that allows these payments to be made quickly and efficiently is of first-order importance, our analysis indicates that a move to a permanent universal income system would have negative welfare implications in the longer run.[83]

[82]A recent opinions poll found that 71% of Europeans believe that the state should give all citizens a basic income (see Garton Ash and Zimmermann (2020)).

[83]See, e.g., the recent NYT, Politico, and NBC news articles on the inabilities of the current unemployment payment system to deal with making payments to unemployed Americans (Schwartz et al., 2020; Cassella and Murphy, 2020; Solon and Glaser, 2020).

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A Stationary Equilibrium

We introduce some notation to define the equilibrium more easily. Let $s_j \in S_j$ be the age-specific state vector of an individual of age j, as defined by the recursive representation of the individual's problems in Section 2. Let the Borel sigma-algebras defined over those state spaces be $\mu = \{\mu_j\}$. Then, a stationary recursive competitive equilibrium for this economy is a collection of: (i) decision rules for education $\{d^e(s_{j=5})\}$, consumption, labor supply, and assets holdings $\{c_j(s_j), h_j(s_j), a'_j(s_j)\}$, parental time and money investments $\{\tau_j(s_j), m_j(s_j)\}$, and parental transfers $\{\hat{a}(s_j)\}$; value functions $\{V_j(s_j), V^s_j(s_j), V^{sw}(s_j)\}$; (iii) aggregate capital and labor inputs $\{K, H_0, H_1\}$; (iv) prices $\{r, w_0, w_1\}$; (v) tax policy $\{\tau_c, \lambda_y, \tau_y, \tau_k, \omega\}$; and (vi) a vector of measures μ such that:

1. Given prices, decision rules solve the respective household problems and $\{V_j(s_j), V^s_j(s_j), V^{sw}(s_j)\}$ are the associated value functions.

2. Given prices, aggregate capital and labor inputs solve the representative firm's problem, i.e., it equates marginal products to prices.

3. Labor market for each education level clears.
   For high-school level:

$$H_0 = \sum_{j=5}^{17} \int_{S_j} E_{j,0}(\theta, \eta)\, h_j(s_j | e = 0)\, d\mu_j + \sum_{j=5}^{5} \int_{S_j} E_{j,1}(\theta)\, h_j(s_j | e = 1)\, d\mu_j$$

   where the first summation is the supply of high-school graduates while the second is that labor supply of college students.
   For college level:

$$H_1 = \sum_{j=6}^{17} \int_{S_j} E_{j,1}(\theta, \eta)\, h_j(s_j | e = 1)\, d\mu_j.$$

4. Asset market clears

$$K = \sum_{j=5}^{20} \int_{S_j} a_j(s_j)\, d\mu_j.$$

5. Good market clears:

$$\sum_{j=5}^{20} \int_{S_j} c_j(s_j)\, d\mu_j + \delta K + G + \sum_{j=5}^{5} \int_{S_j} p_e 1\{d^e_j(s_j) = 1\}\, d\mu_{j=5} + \sum_{j=8}^{9} \int_{S_j} m_j(s_j)\, d\mu_j = F(K, H)$$

   where the last two term on the left hand side represent the expenditures on education and childhood development, respectively.

6. Government budget holds with equality

$$\sum_{j=18}^{20} \int_{S_j} \pi(\theta, e)\, d\mu_j + G = \sum_{j=5}^{20} \int_{S_j} T\left(y\left(s_j\right), k\left(s_j\right), c\left(s_j\right)\right) d\mu_j.$$

   Government expenditures on retirement benefits and G equal net revenues from taxes—which include the lump-sum transfer ω.

7. Individual and aggregate behaviors are consistent: measures μ is a fixed point of $\mu(S) = Q(S, \mu)$ where $Q(S, \cdot)$ is transition function generated by decision rules and exogenous laws of motion, and S is the generic subset of the Borel-sigma algebra defined over the state space.

B Estimation: Details

B.1 Replacement benefits: US Social Security System

The pension replacement rate is obtained from the Old Age Insurance of the US Social Security System. We use education as well as the skill level to estimate a proxy for average lifetime income, on which the replacement benefit is based. Average income at age j is estimated as $\widehat{y}_j(\theta_c, e) = w_e E_{j,e}(\theta_c, \overline{\eta}) \times \overline{h}$ where $\overline{\eta}$ is the average shock (i.e., zero) and $\bar{h}$ are the average hours worked (in the economy). Averaging over j allows average lifetime income $\widehat{y}(\theta_c, e)$ to be calculated and used in (21) to obtain the replacement benefits.

The pension formula is given by

$$\pi(\theta_c, e) = \begin{cases} 0.9\widehat{y}(\theta_c, e) & \text{if } \widehat{y}(\theta_c, e) \leq 0.3\bar{y} \\ 0.9(0.3\bar{y}) + 0.32(\widehat{y}(\theta_c, e) - 0.3\bar{y}) & \text{if } 0.3\bar{y} \leq \widehat{y}(\theta_c, e) \leq 2\bar{y} \\ 0.9(0.3\bar{y}) + 0.32(2 - 0.3)\bar{y} + 0.15(\widehat{y}(\theta_c, e) - 2\bar{y}) & \text{if } 2\bar{y} \leq \widehat{y}(\theta_c, e) \leq 4.1\bar{y} \\ 0.9(0.3\bar{y}) + 0.32(2 - 0.3)\bar{y} + 0.15(4.1 - 2)\bar{y} & \text{if } 4.1\bar{y} \leq \widehat{y}(\theta_c es, e) \end{cases} \tag{21}$$

where $\bar{y}$ is approximately \$288,000 (\$72,000 annually).

B.2 Child Skill Production Function

Cunha et al. (2010) estimates the multistage production functions for children's cognitive and noncognitive skills used in our paper

$$\theta'_{k,q} = \left[\alpha_{1qj}\theta_{k,c}^{\varphi_{jq}} + \alpha_{2qj}\theta_{k,nc}^{\varphi_{jq}} + \alpha_{3qj}\theta_{c}^{\varphi_{jq}} + \alpha_{4qj}\theta_{nc}^{\varphi_{jq}} + \alpha_{5qj}I^{\varphi_{jq}}\right]^{1/\varphi_{jq}} \exp\left(\nu_q\right), \qquad \nu_q \sim N(0, \sigma_{j,\nu_q})$$

for $q \in \{c, nc\}$, i.e., cognitive and noncognitive skills. Using a nonlinear factor model with endogenous inputs, their main estimates, which are based on 2-year periods, are reported in Table B1. We interpret their 1st stage estimates as referring to the period in which the child is born in our model, i.e., the parent's period-age is $j = 8$ (child's period-age is $j' = 1$, or 0–3 years old). The 2nd stage is assumed to refer to the period after the child is born, i.e., the parent's period-age is $j = 9$ (child's period-age is $j' = 2$, or 4–7 years old).

Table B1: Child Skill Production Function: estimates from Cunha et al. (2010)

	Cognitive Skills		Non-Cognitive Skills	
	1st Stage ($j = 8$)	2nd Stage ($j = 9$)	1st Stage ($j = 8$)	2nd Stage ($j = 9$)
Current Cognitive Skills $(\hat{\alpha}_{1qj})$	0.479	0.831	0.000	0.000
	(0.026)	(0.011)	(0.026)	(0.010)
Current Non-Cognitive Skills $(\hat{\alpha}_{2qj})$	0.070	0.001	0.585	0.816
	(0.024)	(0.005)	(0.032)	(0.013)
Parent's Cognitive Skills $(\hat{\alpha}_{3qj})$	0.031	0.073	0.017	0.000
	(0.013)	(0.008)	(0.013)	(0.008)
Parent's Non-Cognitive Skills $(\hat{\alpha}_{4qj})$	0.258	0.051	0.333	0.133
	(0.029)	(0.014)	(0.034)	(0.017)
Investments $(\hat{\alpha}_{5qj})$	0.161	0.044	0.065	0.051
	(0.015)	(0.006)	(0.021)	(0.006)
Complementarity parameter $(\hat{\varphi}_{jq})$	0.313	-1.243	-0.610	-0.551
	(0.134)	(0.125)	(0.215)	(0.169)
Variance of Shocks $\left(\hat{\sigma}_{j,\nu_q}\right)$	0.176	0.087	0.222	0.101
	(0.007)	(0.003)	(0.013)	(0.004)

Notes: Standard errors in parentheses. The 1st stage refers to the period in which the child is born, i.e., the parent's period-age is $j = 8$ (child's period-age is $j' = 1$, or 0–3 years old). The 2nd stage refers to the period after the child is born, i.e., the parent's period-age is $j = 9$ (child's period-age is $j' = 2$, or 4–7 years old).

To go from 2-year periods to 4-year periods (as in our model), we follow the steps explained in Daruich (2019). Using $\hat{\alpha}$ to notate the estimates in Cunha et al. (2010) and α for the values in our model, the two main steps/assumptions for the transformation are: (i) we iterate in the production function under the assumption that the shock ν only takes place in the last iteration, i.e., replace $\theta_{k,q}$ by $\left[\alpha_{1qj}\theta_{k,c}^{\varphi_{jq}} + \alpha_{2qj}\theta_{k,nc}^{\varphi_{jq}} + \alpha_{3qj}\theta_{c}^{\varphi_{jq}} + \alpha_{4qj}\theta_{nc}^{\varphi_{jq}} + \alpha_{5qj}I^{\varphi_{jq}}\right]^{1/\varphi_{jq}}$;[84] and (ii) we assume that the cross-effect of skills (i.e., of cognitive on non-cognitive and of non-cognitive on cognitive) is only updated every two periods.[85] Under these assumptions, the persistence parameter needs to be squared (i.e., $\alpha_{1cj} = \hat{\alpha}_{1cj}^2$ and $\alpha_{2ncj} = \hat{\alpha}_{2ncj}^2$), while other parameters inside the CES function need to be multiplied by 1 plus the persistence parameter (e.g., $\alpha_{2cj} = \left(1 + \hat{\alpha}_{1cj}\right)\hat{\alpha}_{2cj}$).

[84]We assume that the variance of the shock in the 4-year model is twice the one in the 2-year model (i.e., $\sigma j, {\nu_q}^2 = \hat{\sigma} j, {\nu_q}^2$).

[85]Removing this assumption does not change results significantly since the weights corresponding to these elements are very small or even zero in the estimation (in Table B1, see row 2 under columns 1 and 2, as well as row 1 under columns 3 and 4), but it eliminates the CES functional form if $\varphi_{jc} \neq \varphi_{jnc}$.

B.3 Wage Age Profiles

Table B2: Wage Age Profiles by Education Group

	(1) High School	(2) College
Age	0.0312***	0.0557***
	(0.00387)	(0.00577)
Age^2	-0.000271***	-0.000530***
	(4.65e-05)	(6.89e-05)
Inv. Mills Ratio	-0.739***	-0.715***
	(0.0813)	(0.127)
Constant	2.084***	1.927***
	(0.0779)	(0.118)
Observations	9,130	6,015
R-squared	0.051	0.093
# of households	1357	864

*Source: PSID (1968–2016). A period is 4 years long. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The regressions include year fixed effects. To control for selection into work we use a Heckman-selection estimator. The inverse Mills ratios is constructed by estimating the labor force participation equation separately for each education group, using the number of children as well as year-region (as defined by the Census) fixed effects. Standard errors in parentheses.*

B.4 Out of Work Estimation

Table B3: Yearly Out-of-Work Probit Estimation

	(1) High School	(2) College
Working_{t-1}	-1.410	-1.872
	(0.872)	(1.579)
$\text{Working}_{t-1} \times \text{Age}$	0.161***	0.188***
	(0.0389)	(0.0696)
$\text{Working}_{t-1} \times \text{Age}^2$	-0.00153***	-0.00183**
	(0.000409)	(0.000724)
Age	-0.0224	-0.0346
	(0.0364)	(0.0665)
Age^2	-0.000415	-0.000252
	(0.000378)	(0.000686)
Female	-0.199**	-0.0169
	(0.0919)	(0.167)
Constant	1.496*	1.653
	(0.835)	(1.530)
Observations	25,203	14,893

*Source: PSID (1968–1996). Robust standard errors in parentheses. *, **, *** denote statistical significance at the 10, 5, and 1 percent level, respectively. Methodology is explained in the main text.*

B.5 Wage Process Using Yearly Data

In the baseline estimation of the wage process we use wage data averaged over 4 years, following the definition of the model periods. An alternative, as in Krueger and Ludwig (2016), is to estimate the wage process using yearly data and then transform the estimates to 4-year periods. Denoting with $\hat{\rho}^e$ and $\hat{\sigma}^e_z$ the yearly variables, the corresponding 4-year period variables are $\rho^e = (\hat{\rho}^e)^4$ and $\sigma^e_z = \left[1 + (\hat{\rho}^e)^2 + (\hat{\rho}^e)^4 + (\hat{\rho}^e)^6\right] \hat{\sigma}^e_z$. Table B4 shows the results from the estimation, transformed to the 4-year period equivalent. The results are very similar to the baseline estimation reported in Table 1.

Table B4: Returns to skill and wage process by education group using yearly data

	(1) High School	(2) College
λ^e	0.486	0.948
ρ^e	0.891	0.969
σ^e_z	0.034	0.012
$\sigma^e_{\eta_0}$	0.040	0.050

Source: PSID (1968–2016) and NLSY (1979–2012). Estimation using yearly data and then transformed to 4-year periods.

C Welfare Definition: Consumption Equivalence

Let $P = \{0, 1, 2, ...\}$ denote the policy introduced, with $P = 0$ being the initial economy in steady state. We refer to consumption equivalence as the percentage change in consumption (Δ) in the initial economy that makes agents indifferent between the initial economy ($P = 0$) and the one with the policy P in place.

For agents about to become adults (having received the transfer from their parent but not the realization of the school taste shock), in particular, let $\tilde{V}^P_{j=5}(a, \theta, \varepsilon, \Delta)$ be the expected welfare of agents with initial states (a, θ, ε) in the economy P if their consumption (and that of their descendants) were multiplied by $(1 + \Delta)$:

$$\tilde{V}^P_{j=5}(a, \theta, \varepsilon, \Delta) = E^P \left\{ \sum_{j=5}^{j=20} \beta^{(j-5)} u\left(c^P_j (1 + \Delta), h^P_j\right) + \beta^{(12-5)} \delta \tilde{V}^P_{j'=5}(\hat{a}, \theta_k, \varepsilon', \Delta) \right\}$$

where, to simplify notation, we do not include time subscripts (needed for the transition analysis), the school taste parameter, nor show that the policy functions depend on the state. Note that these policy functions are assumed to be unchanged when Δ is introduced (e.g., c^P refers to the consumption chosen by an individual in economy P and is unchanged by Δ). For agents of other ages $j \neq 5$, we define a similar element as $\tilde{V}^P_j(z, \Delta)$ where z is a vector of state variables corresponding to period j.

For any agent we define the consumption equivalence $\Delta^P_j(z)$ as the Δ that makes individuals indifferent between being in the initial economy ($P = 0$) and the one with policy P in place,

$$\tilde{V}^0_j\left(z, \Delta^P_j(z)\right) = \tilde{V}^P_j(z, 0)$$

And we can obtain a measure of average welfare (equivalent to welfare under the veil of ignorance) as

$$\bar{V}^P(\Delta) = \int_z \tilde{V}^P_j(z, \Delta)\, \mu^P_j(z)$$

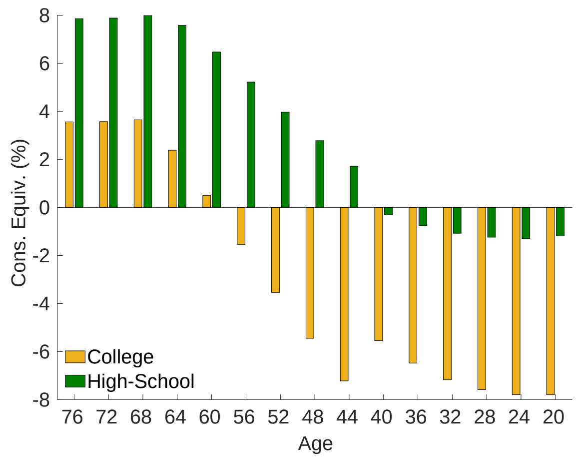
where μ^P_j refers to the distribution over states z in the economy P. Then, we define the consumption equivalence $\bar{\Delta}_j^P$ to be the one that makes a cohort indifferent between the initial steady-state economy and having policy P in place, i.e.,

$$\bar{V}_j^0\left(\bar{\Delta}_j^P\right) = \bar{V}_j^P(0)$$

D Results: Additional Tables and Figures

UBI: Welfare Gains at Period 0 by Age and Education

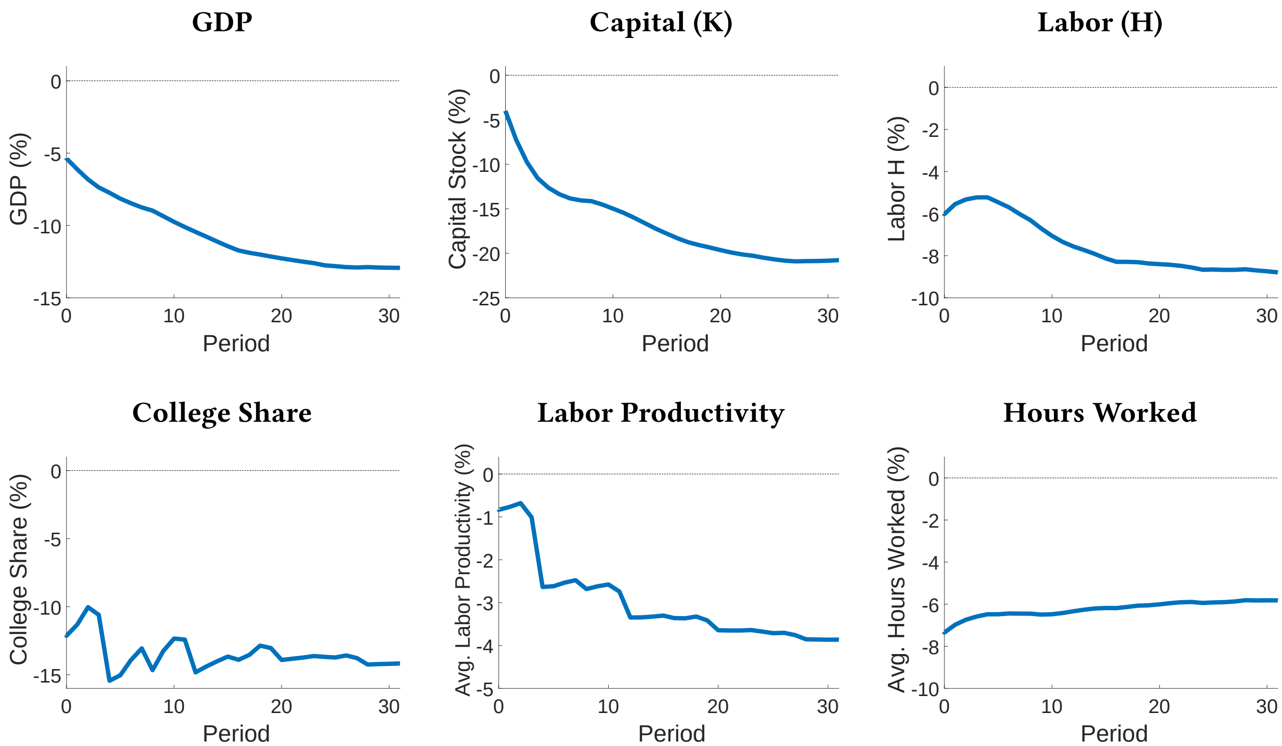
Figure D1: Distribution of Welfare Gains of UBI at Period 0 by Age and Education



Notes: Welfare gain (as measured by consumption equivalence) from the introduction of UBI for different cohorts according to their age when the policy is introduced). Age 16 not shown as whether they will be college educated or not depends on the policy.

UBI: Aggregate Effects During Transition

Figure D2: UBI: Aggregate Effects During Transition



Notes: Labor is aggregate units of labor, as defined by efficiency units of labor H is defined in equation 6. College share and labor productivity (i.e., the value of $e^{\lambda^e \log(\theta_c)}$) are reported for each cohort at age $j = 5$ in each period, starting with $t = 0$. The numbers in the y axes of all figures are in percentage changes from the initial steady state. The 0 in the x axes refers to the period in which the policy is introduced.

UBI: The Effect of Increased Taxation on Various Cohorts

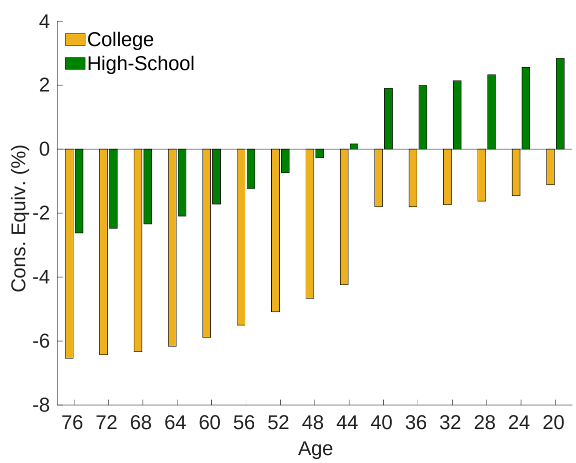
Table D1: UBI: The Effect of Increased Taxation on Various Cohorts

	Cohort				
	-5 (Fixed $\theta, \hat{a}, e$)	**-4 (Fixed $\theta, \hat{a}$)**	**-3 (Fixed θ)**	**0**	**Steady State**
Time Investment Received (%)	0.0	0.0	0.0	-9.9	-13.6
Money Investment Received (%)	0.0	0.0	0.0	-27.4	-36.7
Parental Transfers Received (%)	0.0	0.0	-4.9	-11.2	-34.0
Labor Productivity (%)	0.0	0.7	0.8	-0.5	-1.8
College (%)	0.0	7.2	8.2	3.6	-0.7
Consumption Equivalence (%)	-32.1	-31.6	-32.0	-34.1	-43.2

Notes: We introduce the change in taxes (i.e., $\lambda_{y,t}$) obtained to finance the UBI policy, but without introducing UBI (i.e., no change in ω) and keeping all prices unchanged (i.e., in partial equilibrium). All the numbers reported are in percentage change relative to a cohort born in the initial steady state. Cohort 0 is the cohort born the period in which the UBI policy is introduced. A cohort with a negative number indicates that it was born that (absolute) number of periods prior to the introduction of the policy whereas "Steady State" refers to the cohort born in the new steady state after the policy is introduced. Labor productivity refers to the value of $e^{\lambda^e \log(\theta_c)}$.

UBI Financed With Consumption Tax: Welfare Gains at Period 0 by Age and Education

Figure D3: Distribution of Welfare Gains of UBI Financed with Consumption Tax at Period 0 by Age and Education



Notes: Welfare gain (as measured by consumption equivalence) from the introduction of UBI for different cohorts according to their age when the policy is introduced). Age 16 not shown as whether they will be college educated or not depends on the policy.

Automation with UBI: Long-Run Aggregate Effects

Table D2: Automation with UBI: Long-Run Aggregate Effects

Jobs Destroyed	5%	10%	15%	20%	25%	30%
	Change from Initial Steady State (%)					
GDP	-13.3	-14.4	-15.5	-15.3	-15.4	-15.4
Capital	-20.2	-19.3	-19.4	-17.8	-16.8	-16.2
Labor (Efficiency Units H)	-10.3	-14.1	-17.3	-19.7	-22.0	-24.2
College Share	-11.6	-9.4	-7.6	-3.9	-1.6	1.2
Average Labor Productivity: High-School	-1.9	-1.9	-1.9	-1.8	-1.7	-1.6
Average Labor Productivity: College	-3.7	-3.9	-4.0	-4.4	-4.6	-5.0
Average Hours Worked: High-School	-8.6	-12.4	-15.5	-17.5	-19.5	-21.3
Average Hours Worked: College	-3.6	-5.9	-8.0	-10.4	-12.4	-14.2
Average Hours Worked: All, Excl. Out of Work	-5.7	-5.0	-4.5	-4.3	-4.1	-3.8
Total Factor Productivity $\hat{A}$	0.4	1.8	3.1	4.6	6.2	7.9
High School Weight in Aggregate Labor $\hat{s}$	-0.3	-1.2	-2.1	-2.9	-3.9	-4.7
Interest Rate r	16.8	12.3	7.7	5.1	1.9	-2.1
High-School Wage w_0	-6.3	-4.7	-3.2	-2.2	-1.0	0.5
College Wage w_1	1.1	1.8	2.8	3.8	4.9	6.3
Average Marginal Labor-Income Tax Rate	58.3	61.1	63.3	64.0	64.8	65.2

Notes: Efficiency units of labor H is defined in equation 6. Labor productivity refers to the value of $e^{\lambda^e \log(\theta_c)}$.