Universal Basic Income: A Dynamic Assessment

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Abstract

The idea of universal basic income (UBI)—a set income that is given to all without any conditions—is making an important comeback but there is no real evidence regarding its long-term consequences. This paper provides a very inexpensive evaluation of such a policy by studying its dynamic consequences in a general equilibrium model with imperfect capital markets and labor market shocks, in which households make decisions about education, savings, labor supply, and with intergenerational linkages via skill formation and transfers. The steady state of the model is estimated to match US household data. We find that a UBI policy that gives all households a yearly income equivalent to the poverty line level has different implications in the short versus long run, with younger agents bearing welfare losses and these losses increasing for future generations (operating behind the veil of ignorance). A sizable share of the negative effects is driven by the response of parents (i.e., by endogenous intergenerational linkages) which lead to lower skill formation and education over time. Modeling automation as an increased probability of being hit by an "out-of-work" shock, the model is also used to provide insights on how the benefits of UBI change as the environment becomes riskier.

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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 corona virus epidemic.[1] What do we know about UBIs? What set of issues would an UBI solve and what new set of problems may it create or 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 possible 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 investments and 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.

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 to younger agents and all future generations, operating behind the veil of ignorance, preferring to live in a world without UBI – and 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.[7]

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. Lastly, we contrast the effects of UBI with an alternative universal policy that invests directly in skills – early childhood development (ECD) – and examine how the relative attractiveness of these policies depends on the riskiness of the environment. Our results suggest that 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, while, simultaneously, ECD can be used to increase the likelihood that future cohorts remain productive and employed.

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

[7] This echoes the findings in favor of consumption taxation in the literature, e.g., Coleman (2000) and Correia (2010).

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). In Luduvice (2019), however, parents 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.[8]

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.[9] 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 (ECD) 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

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

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 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) and contrasts this policy with another universal policy of early childhood education. Section 6 concludes. The Appendices contain additional supporting work and results.

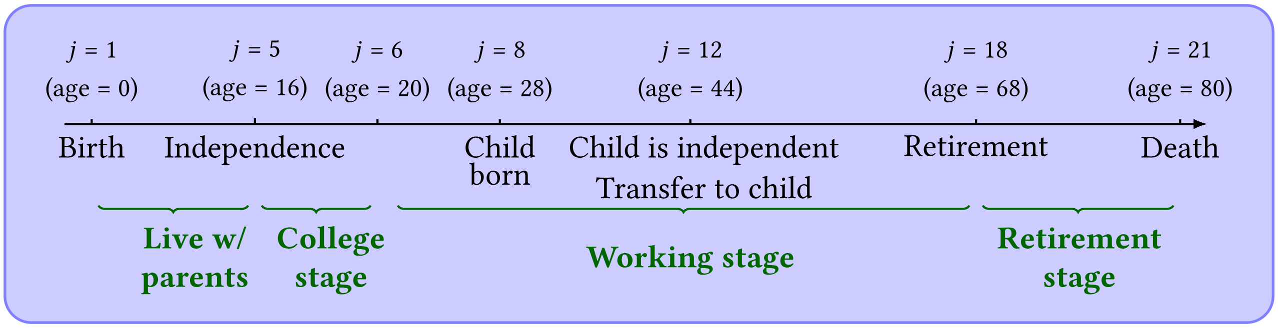
2 The Model

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 Preliminaries

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 until period $j = 20$ (ages 76-79). Agents die before starting period $j = 21$. There is no population growth.

Figure 1: Life Cycle



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 and whether the loan is used to pay for college.[10] 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.[11] 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 the benefits of a UBI policy, it is important to understand how it modifies the progressivity of the existing tax system. We assume that the relationship between after-tax labor income $\tilde{y}$ and pre-tax labor income y is given by:

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

where the tax function used by, e.g., Feldstein (1969), Benabou (2000), and Heathcote et al. (2017), has been augmented to include lump sum transfers ω as well. The parameter τ_y determines the progressivity of the marginal tax rate.[12] As highlighted by the analysis of Heathcote et al. (2017), the same tax function (but which assumes $\omega = 0$) fits the relationship between after-tax and pre-tax income very well for all income quantiles except those at the very bottom of the income distribution. Lump-sum transfers ω in this sense serve two purposes: first, they will help match the after-tax income of the poorest individuals and thus enrich the welfare analysis. Second, and more importantly for our purposes, the UBI policy can be modeled as an increase in ω.[13] Finally, λ moves the tax function for all income groups, so we will

[10]Student loans are explained in detail below.

[11]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.

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

[13]Retirement benefits will also increase by the same amount as the UBI.

estimate it to match the average tax rate. See Section 3 for details on the estimation. We also assume that consumption c and capital income ar are taxed by constant tax rates τ_k and τ_c, so the tax function is:

$$T(y, a, c) = y - \lambda y^{1-\tau_y} + \tau_a a r \mathbf{1}_{a \geq 0} + \tau_c c - \omega \tag{2}$$

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, and $E_j^e(\theta, \eta)$ includes the age profile for their education group, the returns to skills θ, and an idiosyncratic labor productivity shock given by η. 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:

$$Y = AK^{\alpha} H^{1-\alpha} \tag{4}$$

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,

$$H = \left[s H_0^{\Omega} + (1-s) H_1^{\Omega} \right]^{1/\Omega} \tag{5}$$

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.[14]

[14]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

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

We assume that firms are perfectly competitive thus making zero profits and paying unit wages equal to the marginal product of labor, by education:

$$w_0 = A(1-\alpha)s\left(\frac{K}{H}\right)^{\alpha}\left(\frac{H}{H_0}\right)^{1-\Omega} \tag{6}$$

$$w_1 = A(1-\alpha)\,(1-s)\left(\frac{K}{H}\right)^{\alpha}\left(\frac{H}{H_1}\right)^{1-\Omega} \tag{7}$$

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

$$r = A\alpha\left(\frac{H}{K}\right)^{1-\alpha} - \delta_k \tag{8}$$

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

$$u(c,h) = \frac{c^{1-\gamma_c}}{1-\gamma_c} - \mu\frac{h^{1+\gamma_h}}{1+\gamma_h} \tag{9}$$

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 Individual's Maximization Problem and Equilibrium

The Education Stage At $j=5$ (16 years old), the agent faces their first decision: whether to attend college. College lasts one period (i.e., it is over at the end of period 5 — so it lasts 4 years). 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 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.[15] After college, κ no longer affects outcomes. The alternative to 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. We allow college students to 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 computa-

[15]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.

tion, we follow Abbott et al. (Forthcoming) and assume that college student debt is refinanced into a single bond that 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.[16]

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 $\overline{h}$.[17] Thus, the value function of an agent who decides to attend college and has assets a and skills θ is given by:

$$V_j^s(a, \theta, e=1) = \max_{c,a',h} u\left(c, h+\overline{h}\right) + \beta \mathbb{E}_{\eta'|e=1} V_{j+1}\left(\tilde{a}^s(a'), \theta, e=1, \eta'\right) \tag{10}$$

$$c + a' + p_e - y + T(y, a, c) = a(1+r)$$

$$y = hw_0 E_{j=5,e=1}(\theta, \eta=0), \quad a' \geq \underline{a}^s, \quad 0 \leq h \leq 1-\overline{h}, \quad \eta' \sim \Gamma_{j=6,e=1}$$

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. Given the functional form assumption we make in Section 3, this implies that we can evaluate E at the mean value of η (i.e., $\eta = 0$). Furthermore, we have assumed 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

$$V_j(a, \theta, e, \eta) = \max_{c,a',h} u(c, h) + \beta \mathbb{E} V_{j+1}(a', \theta, e, \eta'), \tag{11}$$

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

$$y = hw_e E_{j,e}(\theta, \eta), \quad a' \geq \underline{a}_{j,e}, \quad 0 \leq h \leq 1, \quad \eta' \sim \Gamma_{j,e}(\eta)$$

As indicated, the agent can borrow up to $\underline{a}_{j,e}$, repaying at $r^b > r$, and the return on positive savings is $1 + r$. The return to work is the unit wage w_e scaled by $E_{j,e}(\theta, \eta)$, a function of the worker's age,

[16] 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.

[17] 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.

education, skills, and idiosyncratic labor productivity.

To sum up, at the beginning of period $j = 5$, V_j^{sw} is the value of an agent who chooses between working (as a high-school graduate) versus a college education, i.e.,

$$V_j^{sw}(a, \theta, \varepsilon) = \max \left\{ \mathbb{E}_{\eta|e} V_j(a, \theta, e = 0, \eta), V_j^s(a, \theta, e = 1) - \kappa(\varepsilon, \theta) \right\} \tag{12}$$

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 in period 18, the agent works and their individual problem is equivalent to (11) 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).[18] 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 child's development of skills which have a cognitive and non-cognitive component, i.e., $\theta_k = \left\{\theta_{k,c}, \theta_{k,nc}\right\}$.[19] 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 and non-cognitive skills):

$$\theta'_{k,q} = \left[\alpha_{1qj}\theta_{k,c}^{\varphi_{jq}} + \alpha_{2qj}\theta_{k,nc}^{\varphi_{jq}} + \alpha_{3qj}\theta_{c}^{\varphi_{jq}} + \alpha_{4qj}\theta_{nc}^{\varphi_{jq}} + \alpha_{5qj}I^{\varphi_{jq}}\right]^{1/\varphi_{jq}} \exp\left(\nu_q\right) \tag{13}$$

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

$$I = \bar{A}\left[\alpha_m m^\gamma + (1 - \alpha_m)\tau^\gamma\right]^{1/\gamma} \tag{14}$$

The outer CES, equation (13), 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), however, 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

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

[19] 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.

$j = 8$ and 9 of the parent's life).[20] 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 the child's skill development as shown in the value function below:[21]

$$
\begin{aligned}
V_j\left(a,\theta,e,\eta,\theta_k\right) = \max_{c,a',h,\tau,m}\ & u\left(c,h\right) - v\left(\tau\right) + \beta\mathbb{E}V_{j+1}\left(a',\theta,e,\eta',\theta_k'\right), \qquad (15)\\
& c + a' + m - y + T\left(y,a,c\right) = \begin{cases} a\left(1+r\right) & \text{if } a \geq 0 \\ a\left(1+r^b\right) & \text{if } a < 0 \end{cases}\\
& y = hw_e E_{j,e}\left(\theta,\eta\right), \quad a' \geq \underline{a}_{j,e}, \quad 0 \leq h + \tau \leq 1, \quad \eta' \sim \Gamma_{j,e}(\eta)\\
& m \in \{m_1, m_2, \ldots\}, \quad \tau \in \{\tau_1, \tau_2, \ldots\}\\
& \theta'_{k,q} = \left[\alpha_{1qj}\theta_{k,c}^{\varphi_{jq}} + \alpha_{2qj}\theta_{k,nc}^{\varphi_{jq}} + \alpha_{3qj}\theta_{c}^{\varphi_{jq}} + \alpha_{4qj}\theta_{nc}^{\varphi_{jq}} + \alpha_{5qj}I^{\varphi_{jq}}\right]^{1/\varphi_{jq}} \exp\left(\nu_q\right)\\
& \nu_q \sim N(0, \sigma_{j,\nu_q}) \qquad q \in \{c, nc\}\\
& I = \bar{A}\left[\alpha_m m^\gamma + (1-\alpha_m)\tau^\gamma\right]^{1/\gamma}
\end{aligned}
$$

After these two periods, the child's skills are assumed to be constant and the agent's maximization problem returns to that given in (11) but with an additional state variable θ_k.

Transfer to child: At the beginning of period $j = 12$ but prior to knowing their child's κ realization (i.e., ε), the parent decides the size of the monetary transfer $\hat{a}$ to their child.[22] 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.

$$
\begin{aligned}
V_{\text{transfer}}\left(a,\theta,e,\eta,\theta_k\right) = \max_{\hat{a}} V_{j=12}\left(a-\hat{a},\theta,e,\eta'\right) + \delta\mathbb{E}V^{sw}_{j'=5}\left(\hat{a},\theta_k,\varepsilon\right), \qquad (16)\\
\hat{a} \geq 0, \quad \varepsilon \sim N(\bar{\varepsilon}_e, \sigma_\varepsilon)
\end{aligned}
$$

Notice that, unlike in equation (15), the value function in this stage now includes the continuation value of the child $V^{sw}_{j'=5}$ 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

[20]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).

[21]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.

[22]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.

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 (11).

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 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

$$\begin{aligned} V_j\left(a, \theta, e\right) = \max_{c,a'} & \, u\left(c, 0\right) + \beta V_{j+1}\left(a', \theta, e\right) \\ & c + a' + T\left(\pi(\theta, e), a, c\right) = \pi(\theta, e) + a\left(1 + r\right) \\ & a' \geq 0 \end{aligned} \tag{17}$$

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 demand that the government budget be balanced as the government may have other unmodeled expenses, G. When a new policy such as UBI is introduced, however, we require that any net additional expenses be matched by additional revenue.[23] Thus, G will be defined in the stationary equilibrium as a residual (see Appendix A for the expression). Note that the tax function will be calibrated to match the relationship between pre-tax and after-tax income.

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?

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

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, a UBI policy helps parents increase their investment in their child's skill formation by providing them with funds at a time in life 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 which requires the model to provide an evaluation. The next section estimates the stationary equilibrium of the model which we will then use to provide a quantitative evaluation of policies.

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)).

3.1 Preliminaries

Data and sample selection 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. 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.[24] Similarly, hours worked are the sum of hours worked by the two adults. 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.[25] 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. 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]

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 at the time of (average first) birth $j = 8\,(28)$ and the period after. At age $j = 12\,(44)$, 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 income of a high school graduate 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 $\$6,588$.[27]

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

[25] 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.

[26] An alternative approach that also keeps the computational requirements unchanged (but 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.

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 be $\{-20,000, -34,000\}$ for high-school and college graduates, 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 determines the progressivity of the marginal tax rate and we use the preferred estimation of $\tau_y = 0.18$ from Heathcote et al. (2017). The main advantage of using their estimate is that they use PSID data to take into account deductions (e.g., medical expenses and mortgage interest) and public cash transfers (e.g., AFDC/TANF, SSI, and unemployment benefits) which we too would like to include. The main disadvantage, for our purposes, is that they they do not restrict the sample to two-adult households. 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 $\tau_y = 0.20$, which is in line with their results.[28] More importantly, this suggests that 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% (McDaniel, 2007).[29]

As shown in Figure 1 of Heathcote et al. (2017) that graphs households pre versus post-tax income, 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] The authors present as well an estimation based on Congressional Budget Office data, that suggests $\tau_y = 0.20$; for our calibration we choose their preferred estimate of 0.18.

[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]

Government Spending The government spends on transfers to agents, including retirement transfers. Any amount, G, raised in taxes over that required in the steady state of the model is ignored (i.e., not valued or valued in a linearly independent fashion) and G is held constant in all policy experiments.

Intergenerational Skill Transmission We assume that the child development function takes a nested CES form (see equations 13 and 14). 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 (assuming it is common across skills) to match the intergenerational persistence of gross income, as measured by income rank persistence, of 0.26 as estimated by 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 $\mathrm{Var}\left(\varepsilon_{\theta_{k,c}}\right) = \mathrm{Var}\left(\log\left(\theta_{k,c}\right)\right) - \hat{\rho}_c{}^2\mathrm{Var}\left(\log\left(\theta_c\right)\right)$.

[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 can directly measure parental income while the child is in the house by averaging it over the age-periods $j = 8$ to 11.)

Parental investment in child skills (equation 14) 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 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 $w^e E^e_{ij}$. The efficiency units per unit of time worked are defined by:

$$E^e_{ij} = \epsilon^e_j \psi^e_{ij} \tag{18}$$

where ϵ^e_j is the age profile for the education group e and ψ^e_{ij} is the idiosyncratic labor productivity, that evolves according to:

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

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 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

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

[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.

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 (18) to recover ψ^e_{ij} as a residual in the NLSY data by regressing the log of wages on age.[38] Next, an estimate of λ^e is recovered by regressing our estimate of ψ^e_{ij} against 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

[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).

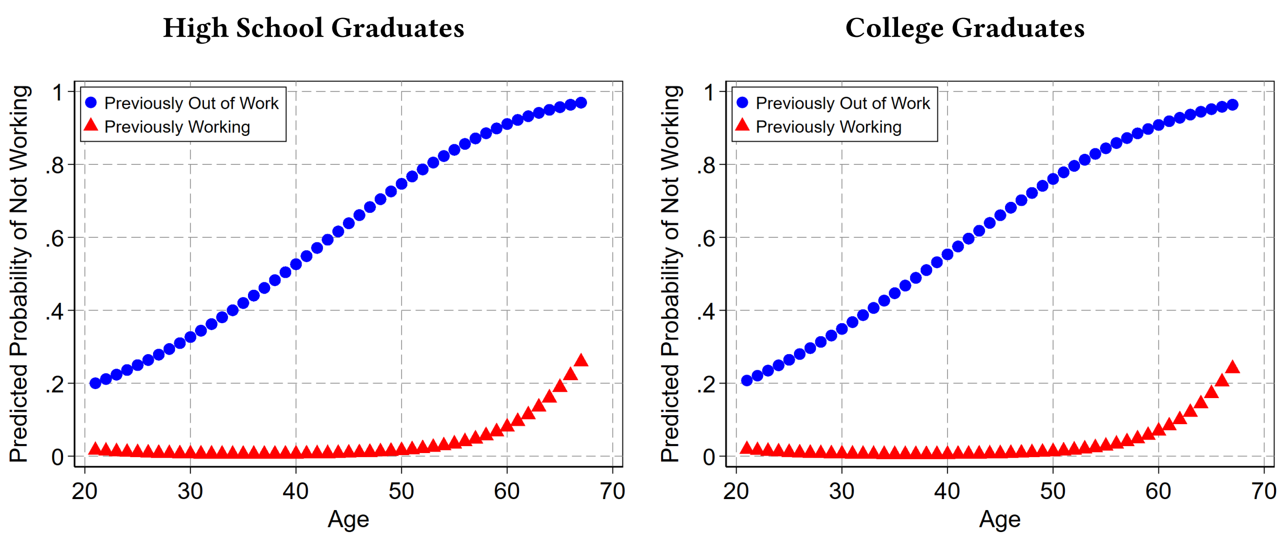
using yearly household labor-income data.[39] We estimate the following Probit model:

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

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 $j-1$ 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.

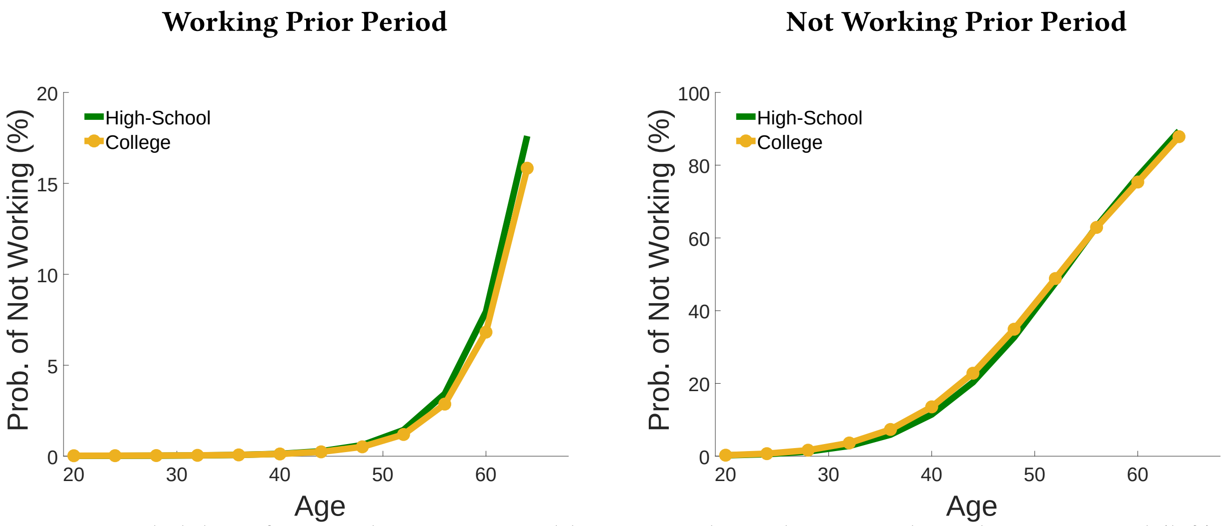
The out-of-work shock is included in η^e_{ij} with a value of $\eta^e_{ij} = -\inf$, which makes the hourly wage zero. The probability of entering this state next period depends on the age and education of individual (as shown by the left panel of figure 3), but is otherwise assumed to be independent of the current value of $\eta^e_{ij} > -\inf$. 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

[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.

exit the out-of-work state start with the lowest value of $\eta^e_{ij} > -\inf$ 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]

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 $N\left(\bar{\varepsilon}_{e_p} - \frac{\sigma^2_\varepsilon}{2}, \sigma_\varepsilon\right)$ 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

[41] The lowest value of η^e_{ij} 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 the one of those 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.

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).[43] 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).

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).[44] 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.[45]

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 5) 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

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

[45] 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 income. See cited paper for details.

representative firm (e.g., Katz and Murphy, 1992; Heckman et al., 1998).

3.2 Simulated Methods of Moments: Results

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.

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			
$\underline{a}^s$	0.09	Of college students of \$23,000	Stafford Loans
$\underline{a}_{j,0}$	0.08	Of high-school workers of \$20,000	Survey of Consumer Finances
$\underline{a}_{j,1}$	0.14	Of college workers of \$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	Fridge elasticity of 1/3	Meghir and Phillips (2010)
Aggregate Production Function			
A	4.18	Average annual income of high-school worker, 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.

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
Skill Formation Productivity: $I = \bar{A}\left[\alpha_m m^\gamma + (1-\alpha_m)t^\gamma\right]^{1/\gamma}$					
ξ	0.03	Parental time disutility of time with children	Avg. weekly hours with children	18.0	15.3
$\bar{A}$	35.7	Returns to investments	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
Government					
λ	0.79	Tax function	Avg. 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.

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.

3.3 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 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.[46] The data shows that families with more education and/or with more labor income invest more in their children (age 0-7), a feature shared by the estimated model. The first two entries in this panel are the coefficients obtained on an indicator for a college 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. The last 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 of annual expenditures on children), which are slightly larger in the model than the data.

Table 4: Validation: Non-Targeted Moments

Moment	**Data**	**Model**
Investments in Children (Daruich, 2019)		
Weekly hours on college ed. parent	2.5–3.7	2.9
Annual expenditures on college ed. parent	666–730	715
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
Labor Income Inequality (PSID)		
Gini	0.32	0.30
Top-Bottom Labor Income Ratio	3.7	3.2
Labor Income Share: 1st Quintile	5.4%	8.0%
Labor Income Share: 2nd Quintile	12.4%	13.7%
Labor Income Share: 3rd Quintile	17.2%	17.1%
Labor Income Share: 4th Quintile	22.9%	23.0%
Labor Income Share: 5th Quintile	42.1%	38.3%
Savings (Inklaar and Timmer, 2013)		
Capital-Output Ratio (annualized)	≈ 3	3.1
Net Return to college (Heckman et al., 2006)		
Yearly return	≈ 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.

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

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 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.[47]

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 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).

[47] 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.

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 (with a standard error of 1.8 percent).[48]

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.[49]

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.[50] 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 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,

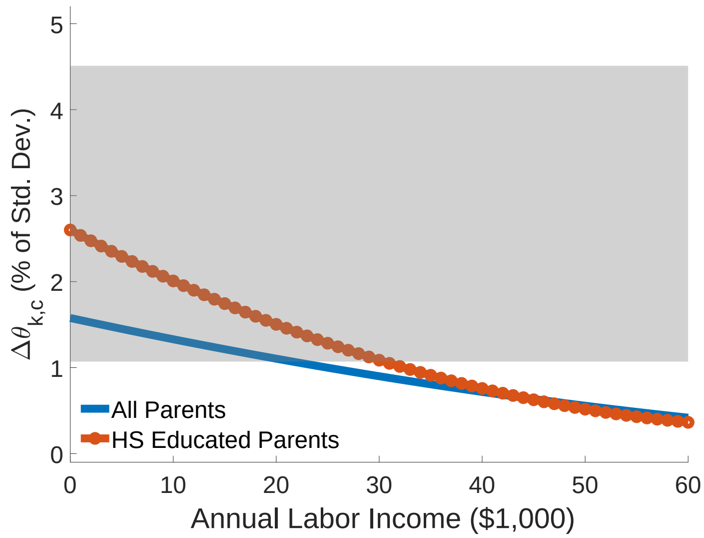
[48]See table 6 in Dahl and Lochner (2017).

[49]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).

[50]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.

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. 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. Every adult (ages 16-79 in our model or periods $j = 5$ to $j = 20$) receives an annual transfer of $5,500 a year or, equivalently, $11,000 per household. This is the transfer level that, in year 2000 dollars, puts a 2-adult household at the poverty line in the absence of any additional income.[51] This policy has been proposed by Democratic presidential candidate Andrew Yang and is also being tested in a small-scale short-run randomized control framework by the YC Research group in Oakland, California.[52]

We assume that the policy is introduced at the beginning of some period t (denoted by $t = 0$), after

[51]The poverty line for a 2-adult household, as defined by the U.S. Census, was $11,235 in the year 2000.
[52]This is the figure evaluated by Hoynes and Rothstein (2019).

individuals have received any shock for that period (e.g., their labor productivity shock, taste shock, etc.) but prior to individuals having made their decisions for that period. The introduction of the policy is assumed to be completely unexpected. 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.

4.1 UBI Baseline Policy: Unchanged Progressivity of the Marginal Labor Income Tax (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).[53] The t subscript on λ indicates that this parameter will need to vary endogenously to keep the budget balanced each period until a new steady state is reached. We refer to this implementation of a UBI policy as the unchanged τ_y case – or our baseline UBI policy – and in the next sections we contrast it with a linear marginal labor tax rate ($\tau_y = 0$) as well as with consumption taxation. In the figures that follow, the unchanged τ_y case is always depicted with blue (solid) lines.

Figure 5 shows the transition effects of the UBI policy on a series of outcomes: i. 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., $1 - \lambda\left(1-\tau_y\right) y^{-\tau_y}$), averaged over all agents with positive labor income y 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.

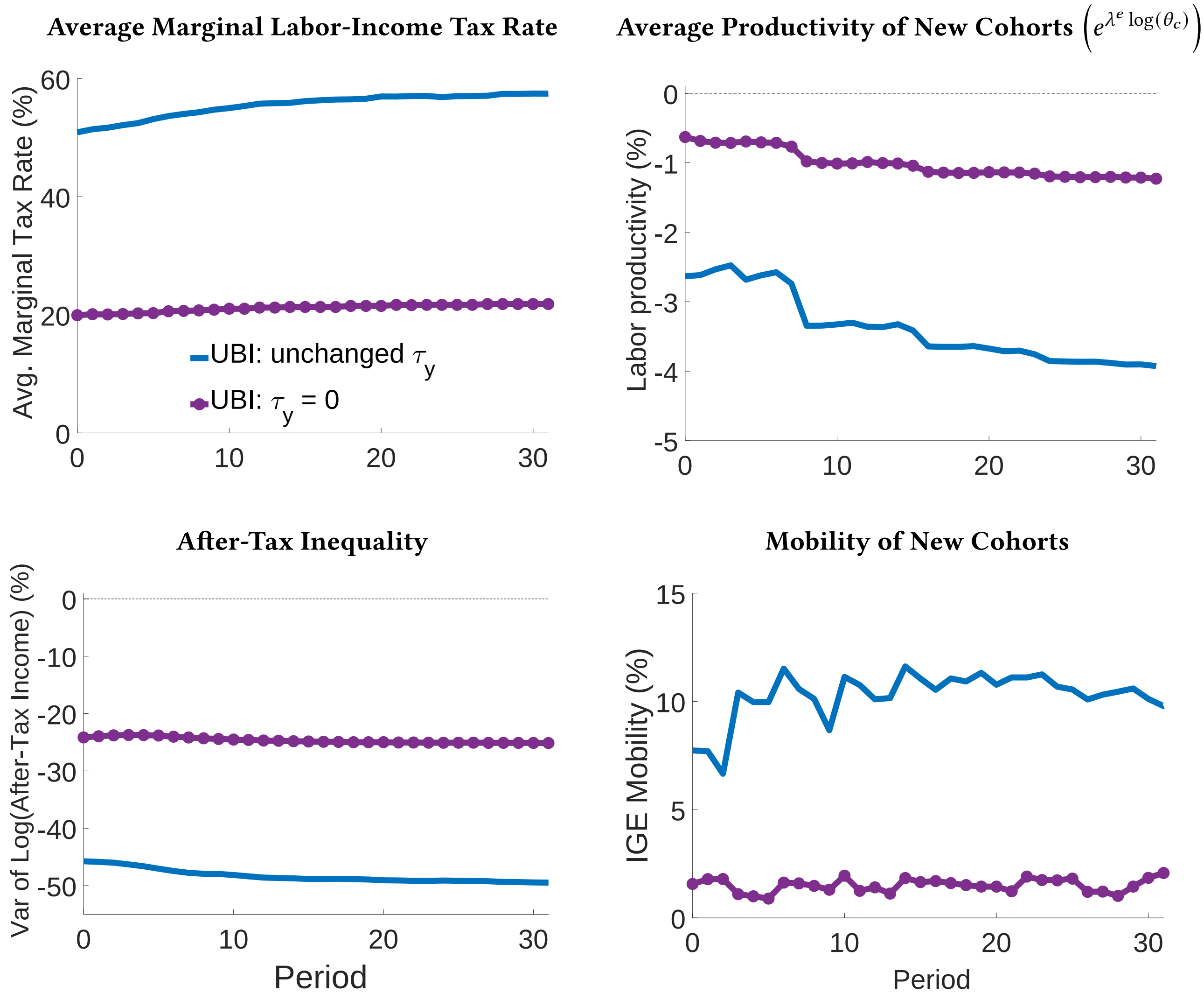
The top left panel of Figure 5 shows that financing the UBI policy requires an initial large increase in average marginal labor-income tax rate of 51% (from 35.9 to 53.6 percent) and that this increases over time to 57% (i.e., to 56.6 percent) above its initial steady state level. The further tax increase is required because the initial increase 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, 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

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

the new steady state.

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, and consumption smoothing increases. The average variance of consumption utility $\left(\frac{c^{1-\gamma_c}}{1-\gamma_c}\right)$ over the life cycle is reduced by 14%. Intergenerational mobility increases: the rank-rank coefficient falls by 8%.

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 baseline economy (i.e., 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.

It is also of interest to understand how the aggregate variables respond in the steady state. 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 (i.e., H as shown in equation 5). 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 D3 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 Baseline (%)
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 5. 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 equivalence for various cohorts.[54] 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.[55]

[54] See Appendix C for details.

[55] 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).

As shown in Figure 6, the UBI policy has large negative effects on future cohorts. The large tax increases required by the policy reduce investment in skills and education, requiring further tax increases in the future. In addition, the parents of future generations themselves have lower education, which further negatively affects children's skill development as shown by the production function (equation 13). 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.[56] 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 unexpected 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 are not born yet or still in the house (i.e., for any cohort $t \leq -10$ as these are of period-age $j \leq 11$ when the policy is introduced).

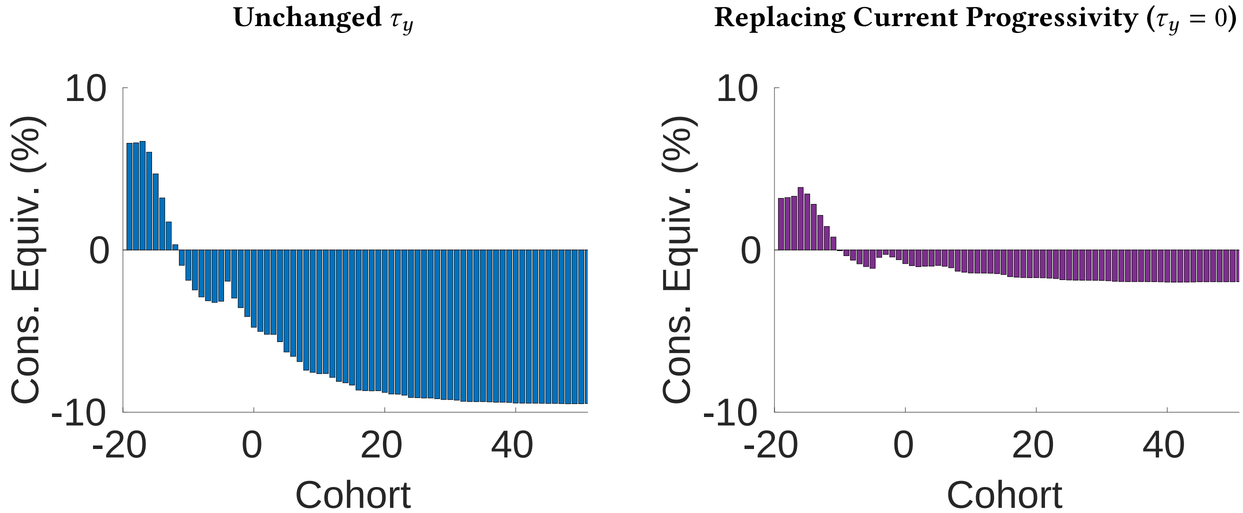
With the above caveat in mind, as shown in Figure 6, agents who are adults when the policy is introduced (i.e, those of period age $j = 5$ to 20) have a welfare gain of 1.0% in consumption equivalent units.[57] The winners tend to be older individuals, those who have been hit by an out-of-work shock, and those without a college education.[58] An important conclusion from the welfare analysis (and independent of the aforementioned caveat) is that all generations as of age $j = 12$ suffer losses. These losses are monotonically increasing as of generation -4, the first generation that becomes adult when the UBI policy is instituted. We turn to exploring the sources of these increasingly large losses and the role of intergenerational linkages in these in the next section.

[56]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).

[57]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 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.

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

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.

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: Duration, 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 the variance in their consumption 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, comes from the possibility that agents will be less likely to invest in their children if the latter are guaranteed a minimum income. 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 7 reports the results from several exercises that shed light on their quantitative 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 $j = 5$). Prices and taxes are maintained at their original steady-state level. 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. As can be seen from the table, this cohort reacts by increasing investments in children substantially (both time and money) and increasing transfers to their children by a large proportion as well. This results in an increase in 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 their welfare (as measured in consumption equivalent terms) of 19.2%. This effect 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.[59]

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 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 are from the new steady state: they reflect outcomes and welfare equivalence only for cohorts born in 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 this UBI benefit, this reduces parents' desire to invest in their child's skills as well as the latter's desire to attend college. The need 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, both money investments in building children's skills as well as transfers to children fall substantially, decreasing 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.

[59]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.

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 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 7: UBI: A Decomposition

Alternative Exercises			**Change from Baseline (%)**						
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**

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 $e^{\lambda^e \log(\theta_c)}$.

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 $\mu_{j=5}(a, \theta, \varepsilon)$.[60] 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 from the baseline economy 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.[61]

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

[61] 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 8 reports the change in time and money investments in child skills, the change in parental transfer, and the ensuing change in labor productivity, college education, and welfare in consumption equivalence units for various cohorts. The cohort indicated by a zero denotes the cohort born when the UBI policy is instituted. Thus parental investment in skills, monetary transfers, and the child's college decision will all be determined in the new policy environment. This is the oldest cohort for which this happens. Cohort -3 was born 3 periods before the UBI policy was instituted at $t = 0$ and thus its skills (θ) were fixed at $t = 0$ but not parental transfers nor college decisions. Cohort -4 and -5 were born 4 and 5 periods before UBI and thus have 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 youngest cohort with 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.[62] 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 (subject to the conditions listed in each row). 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 (t, m, $\hat{a}$, labor productivity, and consumption equivalent welfare) is calculated under three different scenarios, similar in nature to those of the last three rows of Table 7. 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 7, the changes that are reported are the average for the indicated cohort.

As can be seen in Table 8, the large decrease in time and money invested in child skills is suffered already by the first cohort that can be affected – cohort 0 – almost as much as for cohorts born in the new steady state. As in Table 7, 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

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

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

Table 8: 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**
		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**
		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**
		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 baseline economy (i.e., 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: cohort -4 is the one that 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.[63]

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 system. This tax 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, it may be reasonable to think 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

[63] 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.

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.

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.[64] In terms of the average marginal labor-income tax rate, this drops 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 (i.e., in the average over $(1 - \lambda)$ given $\tau_y = 0$) 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 UBI leads to relatively similar average welfare gains for generations who are alive when the policy is introduced as the benchmark case. 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

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

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 of the alternative UBI policy.

UBI and Consumption Taxation

The US stands out among OECD countries for its low reliance on consumption taxation.[65] An alternative to relying on increased taxation of labor income to finance UBI would be to increase the taxation of consumption. 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). 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.[66]

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%. 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.[67]

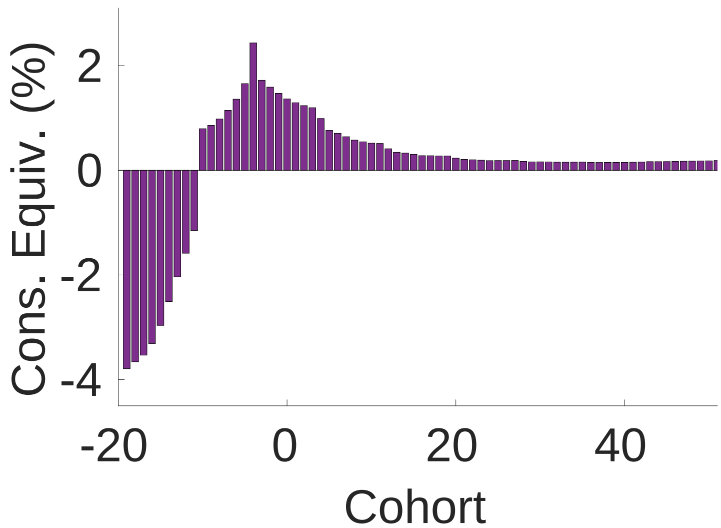
[65]In 2018, taxes on goods and services accounted for 17.6% of tax revenue whereas it accounts for 32.1% on average among other OECD countries (Enache, 2020).

[66]See Appendix Figure D2.

[67]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

By cohort



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 9 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) for the first UBI case of an unchanged τ_y. The pattern of welfare effects is similar to the unchanged τ_y version but, in this case, the welfare gains are on average larger for the adults alive when the policy introduced and the losses smaller for those who will be born in the new steady state.

Table 9: UBI: Robustness

	Unchanged τ_y	**Double σ_z^e**	**UBI substitutes for initial ω**
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.

UBI substitutes for initial ω

As an alternative, we had earlier examined a UBI policy assuming that it might eliminate some of the current social programs and benefits targeted to poorer households. We interpreted this as a reduction of the tax progressivity parameter τ_y, setting it to zero. An alternative might be an unchanged progressivity of the marginal tax rate and instead a reduction in the original level of transfers (the value of ω in the original steady state). We do this by assuming that the original subsidies are eliminated, which is equivalent to 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 in the steady state of the benchmark economy). The third column of Table 9 shows that the welfare effects are similar to those obtained under the original UBI policy.

5 Job Destruction and Universal Policies

As shown, the welfare consequences of a UBI policy are different 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.[68] 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

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

an increase in the proportion of workers who receive an out-of-work shock.[69] In particular, we model increased automation as a permanent increase in the rate with which individuals get hit by an "out-of-work" shock, reflecting the higher rate with which jobs are destroyed.

Concretely, 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 available estimates on the share of current jobs that would be lost in the next 30 years.[70] We leave unchanged the probability of a worker transitioning from out-of-work to employment as how automation affects job creation is unclear. 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, will 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 get hit by an out-of-work shock over the next 28 years as they age to being between 44-48 and 64-68 years old). McKinsey (2017) and OECD (2019) predict the share of current jobs lost 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 automation. 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-school graduate.

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 6). 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 (5). In particular, we adjust s such that if aggregate capital (K) is unchanged from its initial steady-state value and aggregate labor supply (H_0 and H_1) adjusts 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, would remain unchanged.[71] 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 (5) such that, after adjusting s, GDP remains constant at the original capital stock and aggregate labor (with the latter adjusted only be the higher probability of being out of work).[72]

More rigorously, let H_0^*, H_1^*, and K^* be the initial steady-state values of high-school labor, college labor,

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

[70] That is, 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, $e \in \{0,1\}$.

[71] 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).

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

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 (6). 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 10: Automation: Long-Run Aggregate Effects

Jobs Destroyed	5%	10%	15%	20%	25%	30%
	Change from Baseline (%)					
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 5. Labor productivity refers to the value of $e^{\lambda^e \log(\theta_c)}$.

Table 10 reports some key aggregate variable values for the new steady state reached under different occupation/job destruction rates, ranging from 5% to 30%. 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 described previously. Agents who are adults when the job destruction rate increases are on average worse off. Not only are they facing a higher job-destruction rate, but also a higher marginal labor income tax rate as well.[73] Welfare in the steady state is non-monotonic but, of course, does not take into account the transition required to achieve the higher capital stock and more educated labor force.

5.2 UBI In A Riskier Economy

We next revisit how the introduction of a UBI policy affects welfare under these changed environments. The first column of Table 11 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. This policy would be introduced at the same time that the economy became 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 5 (i.e., 16-20 year olds), their college decision made. The third 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).

Table 11: Automation: UBI and ECD Welfare

Jobs Destroyed	Welfare Gains: Cons. Equiv. (%) Adults at $t = 0$ UBI	ECD	Steady State UBI	ECD
Baseline = 3.3%	1.01	-1.89	-9.13	8.82
5.0%	1.28	-1.72	-9.22	8.83
10.0%	1.66	-1.60	-10.02	8.82
15.0%	1.80	-1.61	-11.15	8.73
20.0%	1.97	-1.58	-11.76	8.84
25.0%	2.12	-1.62	-12.55	8.66
30.0%	2.25	-1.64	-13.08	8.48

Notes: Unchanged τ_y UBI policy and ECD 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 columns (1) and (3), living in 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.[74] Future cohorts are also more likely to be out of work, but the losses from UBI are larger since over time the capital stock has fallen, as has investment in child skills and the share of agents that obtain a college

[73] We assume that the change in the frequency of the out-of-work shock was unforeseen at $t = 0$.

[74] Given the caveat that adults whose children are independent (i.e., $j \geq 12$ at $t = 0$) do not take into account the effect of the policy on their children's utility (as explained in Section 4.1) and the fact that children's welfare losses increase with automation, it is clear that the direct effect of UBI on adults' welfare (as opposed to the value of UBI stemming from how it affects their children) must be increasing in the share of jobs destroyed.

education. The average marginal labor-income tax rate required to fund UBI is therefore increasing in the share of jobs destroyed, increasing the welfare losses to the cohorts born in the new steady state.[75]

5.3 Early Childhood Education vs UBI

In this section we provide an evaluation of an alternative universal policy and its interaction with a riskier environment (automation): an early-childhood development (ECD) policy. An ECD policy allows a potentially higher level of investment in children than what parents, given their circumstances, might choose in its absence. This matters because children cannot use their future UBI payments to invest in their own early childhood development nor contract with their parents to obtain a higher level of skills.

We consider an ECD policy based on the programs studied by Garcia et al. (2020). The authors evaluate a randomized control trial (RCT) in which a small group of disadvantaged children were exposed to one of two high-quality early childhood development programs (ABC and CARE in North Carolina) at a cost of approximately $13,500 per year.[76] The children entered the program when they were around 8 weeks old remained in it for five years. They show that the policy led to an increase in the college graduation rate of between 9 and 23 percentage points and predict a return in lifetime earnings (in net present value) of 1.3 dollars for every dollar spent.[77]

To study the effect of an ECD policy in the model, we have the government run a program that costs $13,500 (2000 USD) for 4 years per child, for a total, in net present value (discounted at 4% — the steady state rate of the baseline economy), of $50,964 per child. We assume that these funds are a perfect substitute for parental money m, as shown by the parental investment equation below:

$$I = \bar{A}\left[\alpha_m\,(m+g)^{\gamma} + (1-\alpha_m)\tau^{\gamma}\right]^{1/\gamma} \tag{21}$$

Appendix section B.6 conducts a validation exercise by showing that the model (in partial equilibrium and for lower-income households) generates results in terms of college graduation rates and lifetime earnings that are quantitatively similar to those estimated by Garcia et al. (2020).

ECD vs UBI: The Baseline Model

What are the consequences of an ECD policy and how do they contrast with a UBI? How does the policy comparison change as the level of automation increases? We next turn to these questions by comparing the ECD policy described above with the benchmark UBI policy of section 4.1 before concluding with a comparison under different levels of automation risk. It is important to note from the outset that these

[75] See Appendix Table D1 for more details on the aggregate effects of UBI together with automation.

[76] Note that all prices are expressed in year 2000 dollars.

[77] Garcia et al. observe the education and income of these children at two specific ages (the latest being age 30), from which they estimate the effect on lifetime labor income.

policies have different costs. From the perspective of an individual, the ECD program spends $13,500 (2000 USD) for 4 years on them, for a total, in net present value (discounted at the initial equilibrium interest rate of 4%), of $50,964 per individual. The baseline UBI instead transfers $70,145 (also in net present value evaluated at birth) to each individual. From the perspective of the government, on the other hand, the ECD policy requires it to raise, per period, $13,500x4/20=$2,700 per capita which it then gives to only one cohort per period. The UBI policy requires it to raise $5,500x4x16/20=$17,600 per capita per period which it then spreads uniformly across all adult cohorts each period.[78] In both cases, the additional income needed to finance the policy is accomplished via a change in the parameter λ in the labor tax function so as to maintain a balanced budget.

Figure 8 illustrates how the average marginal tax on labor income, the average productivity of cohorts, the variance of the log of post-tax income, and intergenerational mobility, all measured as defined previously, evolve once the policies are put in place. As shown, as compared to UBI, the ECD policy has a relatively small effect on after-tax inequality whereas it has a very large effect on average labor productivity over time. This difference is reflected in the behavior of the average marginal labor-income tax rate: although the ECD policy requires the average marginal tax rate to be increased early on (from 35.9 to 38.4 percent), the rate falls over time until it is reduced to 36.6 percent, almost back to its original steady-state value. The behavior of this tax rate reflects the fact that the new cohorts are becoming more productive over time, both directly because of the increase in the monetary investment in skills from the policy and because each generation's parents are also more skilled and more educated (which contributes to the skill formation of their descendants and thus increases income).

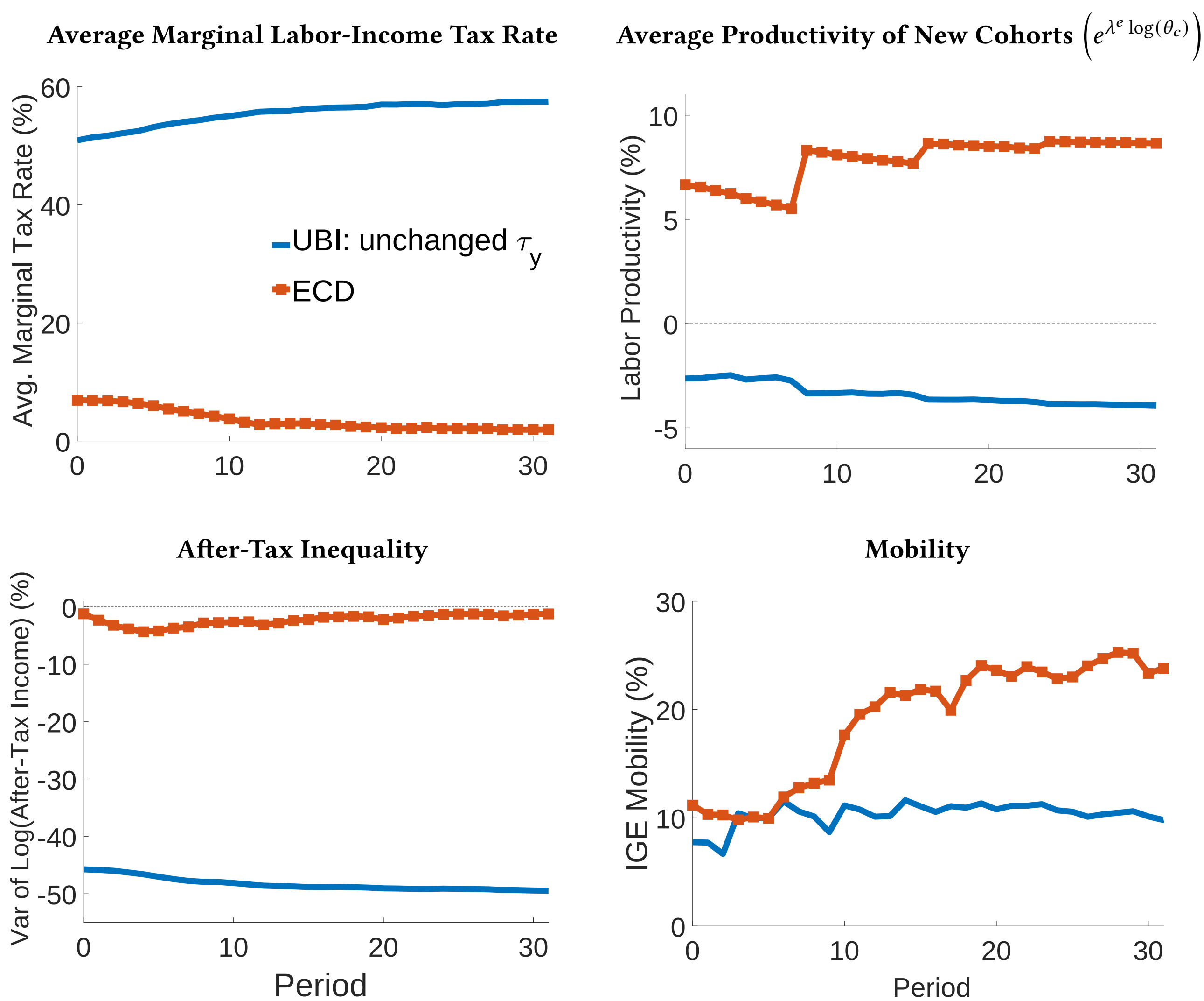
Where do the gains in productivity come from under ECD? Recall that when UBI is introduced, parental money and time investments fall substantially. Even though ECD leads to almost full crowding out of parental financial investments in child skills, the total financial investment in children — the sum of parent and government investment in children's skill development — increases. Moreover, the complementarity between time and money in child skills leads to an almost doubling in parental time. It is important to note that the ECD program is reducing the difference in skill investment for children of poorer households and richer ones. Overall, there is a large increase in intergenerational mobility under this policy — three times greater than under UBI.

UBI and ECD policies also have very different welfare implications. The left panel of Figure 9 — which reproduces Figure 6 to facilitate the comparison — shows the average welfare change (in consumption equivalent units), by cohort, from the introduction of the UBI policy; the right panel shows the equivalent for the ECD policy. A UBI policy, as discussed previously, leads to large welfare losses (of 9.1% in the new steady state) for future cohorts due to the tax increases and the reduction in skills over time as discussed previously. Individuals alive at the time UBI is introduced are generally better off (average welfare gains of 1.0%). ECD, instead, leads to large welfare gains (8.8% in the new steady state) for future cohorts since this policy mitigates the market incompleteness that does not allow children to

[78] An alternative measure of the cost is the percent of the benchmark per capita steady-state GDP required to finance the policy: 2.1% per period for ECD vs 13.6% for UBI.

compensate their parents for greater early childhood investments.[79] Note, however, that despite future cohorts being better off, people alive at the time ECD is introduced are generally worse off (average loss of 1.9%) given that they need to pay higher taxes to finance this policy and that the gains are achieved indirectly through their children and their descendants.

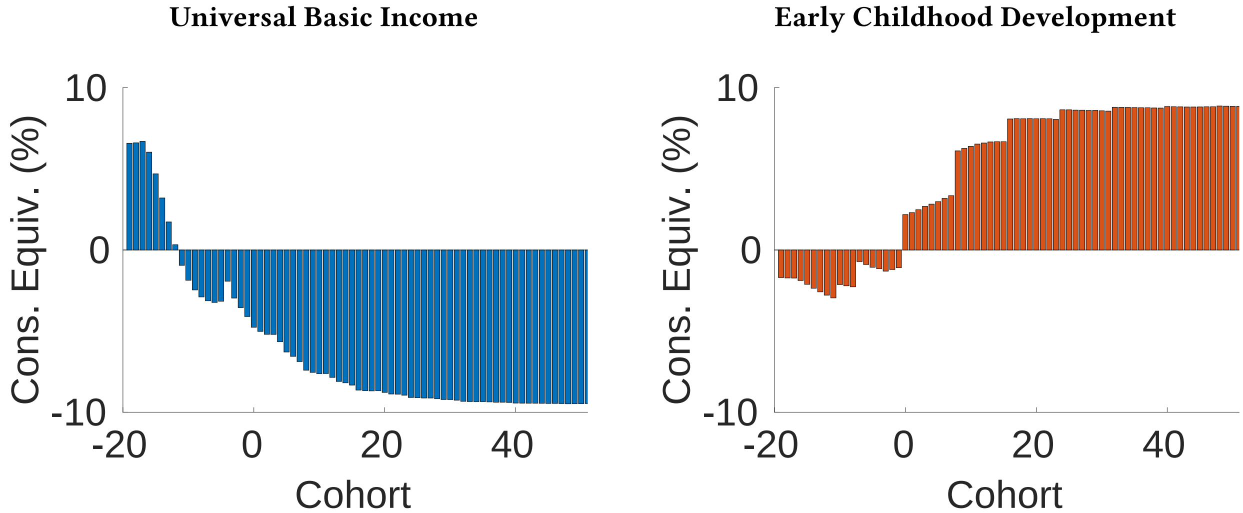
Figure 8: Transition Dynamics of UBI (unchanged τ_y) and ECD



Notes: The baseline UBI policy is in blue (solid) and the ECD policy is in orange (circles). The numbers in the y axes of all figures are in percentage change from the baseline economy (i.e., the initial steady state). The 0 in the x axis of the average marginal labor tax and after-tax inequality 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.

[79] ECD welfare gains exhibit some jumps across cohorts which show the importance of parents in an agent's welfare: The first jump is given by the first cohort born to intervened parents, the second is the first cohort born to intervened parents and grandparents, etc.. These as the counterparts of the jumps in productivity by cohort seen in Figure 8.

Figure 9: Welfare Dynamics of UBI (unchanged τ_y) and ECD



Notes: Welfare gain (as measured by consumption equivalence) from the introduction of UBI (left) and ECD (right) 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.

ECD vs UBI: A Riskier Environment

Lastly, we turn to the effect of a riskier environment from automation/robotization. Table 11 provides a comparison of outcomes of ECD for an economy with increasing levels of "out-of-work" risk, allowing side-by-side contrasts with the UBI policy. Unlike UBI, Table 11 shows that the ECD policy provides a large and rather stable gain in the long run in an environment with large out-of-work shocks. The welfare consequence of ECD for the adults alive at $t = 0$ are almost unaffected by the rate of automation.

Altogether, the results above suggest that a combination of policies may improve welfare for all, on average. A 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. Applied simultaneously, an ECD policy may improve long-run welfare by allowing future cohorts to increase their skills, education, and probability of employment. Thus, some combination of a transitional UBI policy and a long-run subsidy to the formation of skills in childhood may well be welfare improving for all.

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.

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 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: at least 40% of the welfare loss is due to parents choosing to make lower skill investments and transfers to their children.

Motivated by currents fears of automation/robotization, this paper also examines 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.[80] 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 entail large losses in the longer run.[81]

[80] 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)).

[81] 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 $\{V_j(s_j), V_j^s(s_j), V^{sw}(s_j)\}$; (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 $\{V_j(s_j), V_j^s(s_j), V^{sw}(s_j)\}$ 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:

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

   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 (22) to obtain the replacement benefits.

The pension formula is given by

$$\pi(\theta_c, e) = \begin{cases} 0.9\widehat{y}(\theta_c, e) & \text{if } \widehat{y}(\theta_c, e) \le 0.3\bar{y} \\ 0.9(0.3\bar{y}) + 0.32(\widehat{y}(\theta_c, e) - 0.3\bar{y}) & \text{if } 0.3\bar{y} \le \widehat{y}(\theta_c, e) \le 2\bar{y} \\ 0.9(0.3\bar{y}) + 0.32(2 - 0.3)\bar{y} + 0.15(\widehat{y}(\theta_c, e) - 2\bar{y}) & \text{if } 2\bar{y} \le \widehat{y}(\theta_c, e) \le 4.1\bar{y} \\ 0.9(0.3\bar{y}) + 0.32(2 - 0.3)\bar{y} + 0.15(4.1 - 2)\bar{y} & \text{if } 4.1\bar{y} \le \widehat{y}(\theta_c es, e) \end{cases} \tag{22}$$

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 $\left[\alpha_{1qj}\theta_{k,c}^{\varphi_{jq}} + \alpha_{2qj}\theta_{k,nc}^{\varphi_{jq}} + \alpha_{3qj}\theta_{c}^{\varphi_{jq}} + \alpha_{4qj}\theta_{nc}^{\varphi_{jq}} + \alpha_{5qj}I^{\varphi_{jq}}\right]^{1/\varphi_{jq}}$;[82] 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.[83] Under these assumptions, the persistence parameter needs to be squared (i.e., $\alpha_{1cj} = \hat{\alpha}_{1cj}^2$

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

[83] 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 $\varphi_{jc} \neq \varphi_{jnc}$.

and $\alpha_{2ncj} = \hat{\alpha}^2_{2ncj}$), while other parameters inside the CES function need to be multiplied by 1 plus the persistence parameter (e.g., $\alpha_{2cj} = \left(1 + \hat{\alpha}_{1cj}\right) \hat{\alpha}_{2cj}$).

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 fixed effects. Standard errors in parentheses.*

B.4 Out of Work Estimation

Table B3: Yearly Out-of-Work Probit Estimation

VARIABLES	(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 $\hat{\sigma}_z^e$ the yearly variables, the corresponding 4-year period variables are $\rho^e = (\hat{\rho}^e)^4$ and $\sigma_z^e = \left[1 + (\hat{\rho}^e)^2 + (\hat{\rho}^e)^4 + (\hat{\rho}^e)^6\right] \hat{\sigma}_z^e$. 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_z^e	0.034	0.012
$\sigma_{\eta_0}^e$	0.040	0.050

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

B.6 Validation: Early Childhood Development Program

Here we validate the model's predictions regarding the ECD policy. Garcia et al. (2020) study a randomized control trial (RCT) in which a small group of disadvantaged children were exposed to one of two high-quality early childhood development programs (ABC and CARE in North Carolina) at a cost of approximately $13,500 per year.[84] The children entered the program when they were around 8 weeks old remained in it for five years. They show that the policy led to an increase in the college graduation rate of between 9 and 23 percentage points and predict a return in lifetime earnings (in net present value) of 1.3 dollars for every dollar spent.[85]

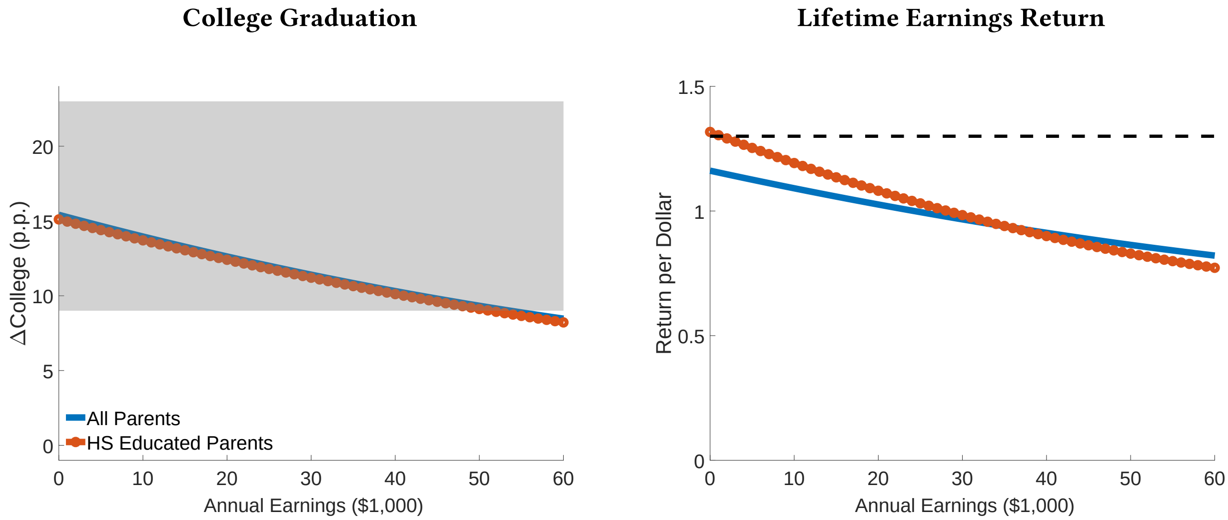
We introduce a similar policy in the model by having the government unexpectedly spend money in the early development of children. We give parents 13,500 x 4 in the first period in which they have a child and 13,500 in the second period to approximate 5 years of funding. The program is assumed to exist only for one generation and this is common knowledge. Similar to the case of the cash-transfer validation, the policy in the model is introduced as a partial-equilibrium experiment, i.e., prices are kept constant at their steady state value as only a few people were affected.

Figure B1 shows the model prediction of the percentage point increase in college graduates (left panel) and in the return per dollar (right panel) as a function of family income. As shown, the model predicts large increases in college graduates, similar to the estimates given by the study. For example, for children whose parents' annual income is $10,000, college graduation rates increase by 14.1 percentage points. The rate of return predicted by the model for these same children is 1.10, and 1.20 if we focus on children of high-school graduates. Similar to the case of cash-transfers, the model predicts larger gains (both in education and lifetime earnings) for children of low-income parents.

[84] Note that all prices are expressed in year 2000 dollars.

[85] Garcia et al. observe the education and income of these children at two specific ages (the latest being age 30), from which they estimate the effect on lifetime labor income.

Figure B1: Validation: Early Childhood Program



Notes: The blue (solid) line is for all parents; the red (circles) line is for high school graduate parents. Effects are calculated for many families and we report the smoothed average effect per income level. The gray area represents the empirical estimates by Garcia et al. (2020) +/- 1 std dev. The dashed line represents the empirical estimate of lifetime income return per dollar invested (in NPV) (no standard errors provided).

C Welfare Definition: Consumption Equivalence

Let $P = \{0, 1, 2, \ldots\}$ 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 $\Delta^P(z)$ as the Δ that makes individuals indifferent between being in the baseline economy ($P = 0$) and the one with policy P in place,

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

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

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

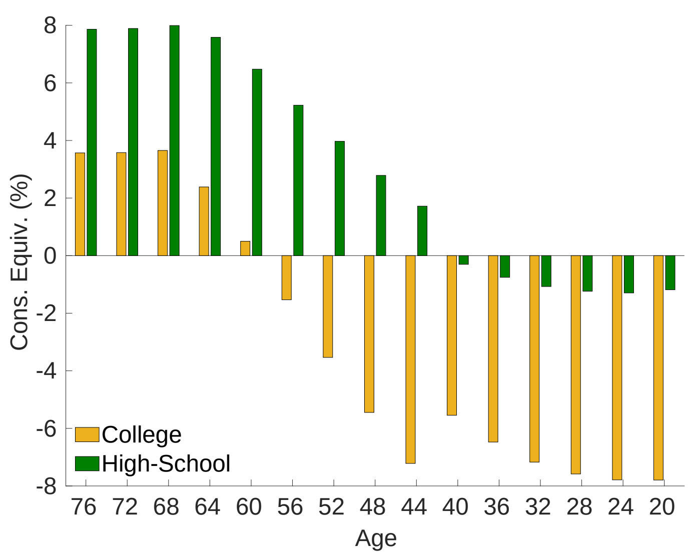
where μ_j^P refers to the distribution over states z in the economy P. Then, we define the consumption equivalence $\bar{\Delta}^P$ to be the one that makes a cohort indifferent between the baseline economy and having policy P in place, i.e.,

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

D Results: Additional Tables and Figures

UBI: Welfare Gains at Period 0 by Age and Education

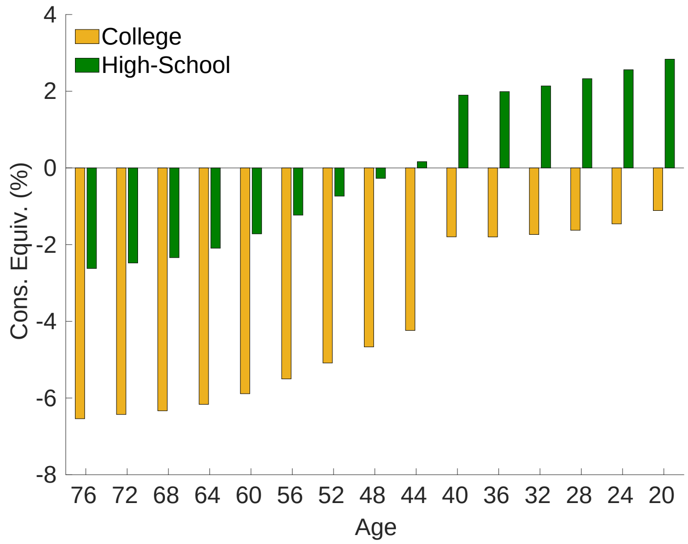
Figure D1: Distribution of Welfare Gains of UBI at Period 0 by Age and Education



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

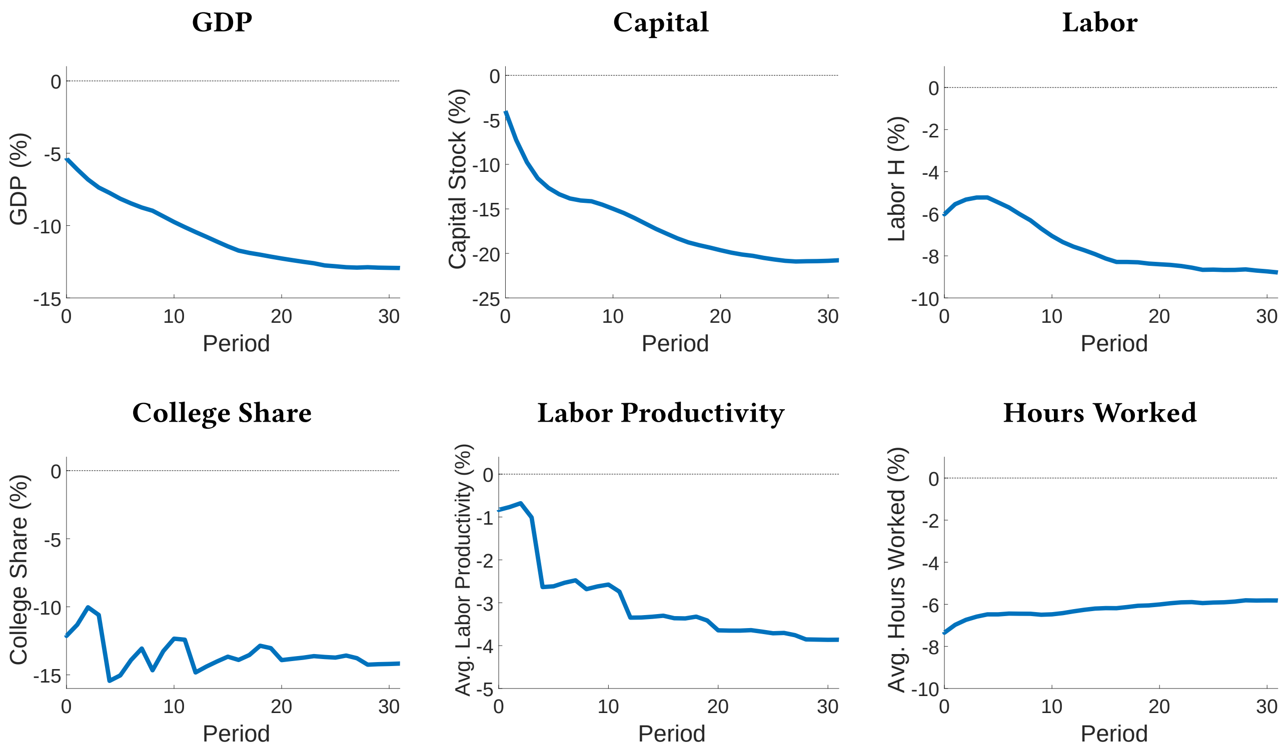
Figure D2: Distribution of Welfare Gains of UBI Financed with Consumption Tax at Period 0 by Age and Education



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.

UBI: Aggregate Effects During Transition

Figure D3: UBI: Aggregate Effects During Transition



Notes: Efficiency units of labor H is defined in equation 5. College share and labor productivity (i.e., the value of $e^{\lambda^e \log(\theta_c)}$) are for the cohorts of age $j = 5$ in each period. The numbers in the y axes of all figures are in percentage changes from the baseline economy (i.e., the initial steady state). The 0 in the x axes refers to the period in which the policy is introduced.

Automation with UBI: Aggregate Effects

Table D1: Automation + UBI: Long-Run Aggregate Effects

Jobs Destroyed	5%	10%	15%	20%	25%	30%
	Change from Baseline (%)					
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
Aggregate Production Function $\hat{s}$	-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 5. Labor productivity refers to the value of $e^{\lambda^e \log(\theta_c)}$.