The Macroeconomic Effects of Universal Basic Income Programs

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Abstract

What are the consequences of a nationwide reform of a transfer system based on means-testing towards one of unconditional transfers? I answer this question with a quantitative model to assess the general equilibrium, inequality, and welfare effects of substituting the current U.S. income security system with a Universal Basic Income (UBI) policy. To do so, I develop an overlapping generations model with idiosyncratic income risk that incorporates intensive and extensive margins of labor supply, on-the-job learning, and child-bearing costs. The tax-transfer system closely mimics the U.S. design. I calibrate the model to the U.S. economy and conduct counterfactual analyses that implement reforms towards a UBI. I find that an expenditure-neutral reform has moderate impacts on the labor supply response of agents but induces aggregate capital and output to grow due to larger precautionary savings. A UBI of \$ 1,000 monthly requires a substantial increase in the tax rate of consumption used to clear the government budget and leads to an overall decrease of the macroeconomic aggregates, stemming from a sharp drop in labor. In both cases, the economy has more disposable income but less consumption at the bottom of their distributions. The UBI economy constitutes a welfare loss at the transition if expenditure-neutral and results in a gain in the second scenario. Despite relative losses, a majority of newborn households supports both UBI reforms.

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JEL Classifications: E21, H24, J22

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1 Introduction

A Universal Basic Income (UBI) is an unconditional transfer given to all citizens of a given region or country. In the last few years, pilot programs and experiments have been proposed, launched, or are ongoing in countries such as Canada, Brazil, Finland[1], Kenya, Switzerland, Uganda, and the United States[2]. The idea is far from new in Economics as similar concepts have been proposed by James Meade, Milton Friedman - with the Negative Income Tax -, Anthony Atkinson, among others (Meade, 1935; Friedman, 1962; Atkinson, 1995) and has been long discussed by thinkers across all traditions of the political spectrum (Parijs and Vanderborght, 2017). In a nationwide context, the span of proposed policies is fairly broad: from large, one-time grants at the beginning of working age on top of the already existing programs to an entire substitution of the welfare system, including Social Security (SS) and health benefits (Murray, 2006; Thigpen, 2016).

The return of the UBI concept to the policy debate and, more recently, to the Economics literature, is due to both the economic incentives intrinsic to its simple design and to the recent set of trends in inequality, public finance and the labor market that have been attracting Economists' attention. On the incentives side, the UBI can potentially reduce inefficiencies at the microeconomic level. First, as it is a lump-sum transfer, it does not distort individuals' decisions and avoid threshold traps that might be induced by any means-testings. Second, it is untargeted and can yield a 100% take-up rate as it avoids stigma or any other latent frictions for program eligibility and applications. Third, it does not require any monitoring or bookkeeping and can reduce government operational costs.

In the last 20 years, there has been a steady growth of both federal spending and participation in means-tested income security programs such as the Earned Income Tax Credit (EITC) or the Supplemental Nutrition Assistance Program (SNAP). The eligibility requirements of such programs yield phase-out effects that generate discontinuities in

[1] The Finnish experiment has already been concluded. The program ran through 2017-18 and the preliminary results for the first year can be found in the recently released report (link).

[2] A few examples are the Y Combinator randomized control trial, the Stockton Economic Empowerment Demonstration in California, and the democratic candidate Andrew Yang's "Freedom Dividend" proposal. A longstanding program of unconditional transfers in the U.S. is the *Alaska Permanent Fund Dividend*, which will be later discussed in detail in this text.

after-tax income with effective marginal tax rates on the order of 30-39%, for more than 50% of low- and moderate-income households (CBO, 2013, 2015). At the same time, income inequality has sharply risen as the top 1% household earns today 24.1 times the median household income, a figure that was 8.6 in 1976 (Nakajima, 2017). While such growth of the very top is often addressed by the literature, the catching-up of the bottom when accruing its share of national income is a redistribution matter in which the UBI is often raised as a competitive instrument. Finally, the observed decline of labor force participation, especially among young men, when paired with the current and expected rise of automation, has triggered the concern on how to adapt the welfare system in an economic environment with pervasive joblessness (Michaels, 2017; Lowrey, 2018; Acemoglu and Restrepo, 2019).

However, as in any reform proposal, UBI-type programs gather significant drawbacks that raise skepticism towards both the effectiveness and the feasibility of its implementation (Ravaillon, 2018; Kearney and Mogstad, 2019). On top of the list of concerns is its potential large cost due to its universality and how it would be financed. Questions are raised regarding possible taxation counterparts that could be similarly as distortionary as means-testing thresholds or whether it could crowd-out the budget from other programs directed to poverty alleviation. A second concern is its potential disincentive to work due to large income effects, especially at the bottom of the income distribution, which leans the balance towards the need for work requirements in the EITC fashion. Lastly, there is the natural economic intuition of equating marginal utilities behind economic redistribution. The UBI is thus often argued as not intrinsically designed to generate equity since it pays same benefits to the rich and the poor.

This paper assesses the effects of substituting the current income security share of the U.S. welfare system for a UBI. Despite the growing momentum of the debate and the many unanswered questions, the macroeconomic literature still lacks a detailed understanding of what would be the general equilibrium, distributional and welfare effects of a large scale reform of the welfare system that implements a UBI. More specifically, what would be expected of the labor supply and accrual of disposable income for different strands of the distribution in such reconstruction and its overall effect on inequality. In order to tackle this task, I numerically solve a dynamic general equilibrium model that is able to provide micro-founded life-cycle and budgetary implications of such a broad welfare state reform as well as a normative assessment that relies on rich dynamics and heterogeneity taking into account the overall impact on inequality. With respect to the literature, this work is on the tradition of evaluating reforms and transfer programs in heterogeneous agents models (Lopez-Daneri, 2016; Pashchenko and Porapakkarm, 2017; Wellschmied, 2018; Ortigueira and Siassi, 2019; Guner et al., 2019a,b; Hannusch, 2019; Berriel and Zilberman, 2011) and is an addition from the quantitative macroeconomics side to a growing list of recent studies that focus on the UBI policy (Jones and Marinescu, 2018; Hanna and Olken, 2018; Banerjee et al., 2019; Ghatak and Maniquet, 2019; Hoynes and Rothstein, 2019).

I develop a large-scale overlapping generations model with retirement and heterogeneity across households that incorporates both intensive and extensive margins of labor supply, human capital accumulation through labor market experience, and child-bearing costs. Households are also heterogeneous with respect to estimated permanent ability and idiosyncratic productivity shocks. The model has a welfare system composed of Social and Income Security (henceforth IS and SS systems) that mimics the U.S. structure accounting for means-testing requirements and its taxation counterparts. The IS system is composed of the Earned Income Tax Credit (EITC), means-tested transfers such as the Supplemental Nutrition Assistance Program (SNAP), the Temporary Assistance for Needy Families (TANF) and the Supplemental Security Income (SSI), the latter only available through retirement. The SS system is budget-balanced and pays retirement benefits to all households in the economy. I calibrate the model to the U.S. economy, and with this macroeconomic toolkit, I conduct counterfactual analyses of implementing reforms in the welfare system towards a UBI and evaluate the welfare implications of means-tested versus unconditional transfers.

In order to bring this model to the data, I estimate a wage process taking into account the target population of cash transfers recipients using the 2008 panel of the *Survey of*

Income and Program Participation (SIPP) in a similar fashion to Heathcote et al. (2010) and calibrate parameters to match data moments. The model can successfully replicate both the non-targeted earnings and wealth distribution of the U.S due to a combination of the steepness of the earnings profile of high productivity households via human capital accumulation and the means-testing transfer schedule. In a further step, I conduct a counterfactual exercise in the model environment designed to approximate the effects of the Alaska Permanent Fund dividend. As empirically shown in Jones and Marinescu (2018), this program has macroeconomic outcomes, and the model is able to, in an off-sample fashion, generate aggregate responses that are in the same sign an order of magnitude of the ones estimated. Moreover, by disentangling partial and general equilibrium effects, I show that the model requires the latter and the adjustment of labor supply to the change in the competitive wage to better match the evidence in the data.

The first counterfactual I implement is an expenditure-neutral reform that keeps constant the total amount of budget outlays in transfers and let the tax rate on consumption endogenously adjust to balance the government's budget. The aggregate response encompasses an increase of 10% in physical capital with an accompanying decrease in the equilibrium interest rate. The result is driven by agents that, early in their life-cycle, are at the bottom of the wealth distribution in the benchmark scenario and now save more due to the absence of means-testing and the average level of transfers in the counterfactual economy. Pushed by an increase in the aggregate capital, output increases by 5.2%. The income effect generated by the transfers affects the aggregate labor market inducing a small increase in total hours, reflecting the rise in the intensive margin of releasing households from the incentive to work less in order to fall inside the means-testing brackets. At the same time, the extensive margin reacts in the opposite direction with a decrease of labor force participation of 1 percentage point. This reform reduces the tax effort towards revenues as the endogenous tax rate on consumption decreases from 8.1% to 7.8%.

In my second counterfactual exercise, I implement a UBI reform similar to the one proposed by Andrew Yang - Democratic presidential candidate for the 2020 elections in the US. I let the level of aggregate transfers be the equivalent of 20% of output in the benchmark economy. This yields a transfer of approximately US$12,000 annually to each household in the economy. In this scenario, - and not surprisingly - the tax rate on consumption needs to increase 22 percentage points in order to balance the government's budget. The aggregate response of the economy is a contraction of both capital and output, stemming simultaneously from the drop in hours, the decline in labor force participation, and the decrease of precautionary savings motive at the bottom generated by the high level of the consumption floor. In terms of the impact on inequality, both UBI reforms increase the Gini coefficient for pre-tax earnings and wealth, mostly due to the selection mechanism arising from the high productivity agents that remain in the labor force and can buffer consumption through a higher level of savings. However, inequality in disposable income at the very bottom of the distribution decreases in both cases, driven by a reduction of the means accrued by the middle-class. This result is followed by less consumption redistribution towards the same bottom 20% in both economies, which is reshufflled towards the upper-middle-class.

I also conduct a normative analysis of the reforms by evaluating the model's responses in welfare. Under a utilitarian Social Welfare Function, the Consumption Equivalent Variation required for the UBI alternative to attain the same level of welfare of the current system at the beginning of the life-cycle is of -0.20%. Alternatively, the generous UBI transfer improves welfare by 0.12%. The transitional dynamics towards the generous UBI economy exhibits differences in welfare relative to the steady-state levels due to the sharp drop in labor coupled with a slow adjustment in capital. The decomposition of welfare at the age dimension shows that the welfare losses in the first counterfactual scenario are more pronounced during earlier ages, as households that have children receive lower transfers when compared to the ones of the means-tested system, which includes the different brackets per children of the EITC. The second reform has gains across all generations alive at the period of the reform. Both counterfactuals can constitute a majority of winners that would vote in favor of the reform. The share of winners closely tracks the age breakdown, with approval of 83.9% for the second proposal. Moreover, the first counterfactual is beneficial to high ability households, while the second counterfactual is preferred by the ones with low ability.

This paper is organized as follows. In the next section, I present a review of the related literature. In Section 3, I construct the setting of my quantitative model, provide intuition about the underlying theory, and define the recursive competitive equilibrium. In the subsequent Section 4, I describe the calibration used to map the model to the data. Section 5 presents the results for the Benchmark Economy and the properties of the initial steady-state. Section 6 lays-out the quantitative exercises explored and the results for two counterfactual UBI reforms. In Section 7, I explore the results for the transitional dynamics between the initial steady-state and the final steady-state of the reforms. Section 8 conducts the normative evaluation of the reforms by exploring different measures of welfare. The last section states my conclusions.

2 Related Literature

I begin by briefly discussing the empirical evidence on the labor market effect of unconditional transfers. In a comprehensive summary, Marinescu (2017) documents the empirical findings of related experiments such as the NIT, casino dividends recipients, and lottery winners. She observes that overall, in such programs, there is either no effect on labor market supply or a slight but not statistically significant reduction in work and earnings. For the case of Permanent Fund, one of the few clear examples of windfall transfers in a wide geographic region, Jones and Marinescu (2018) use a synthetic control method and find that the dividend cash transfer had no effect on the employment to population ratio and increased part-time work by 1.8 percentage point, suggesting a close to zero income effect for the extensive margin. In section 5.3, I will refer to these estimates and use them as a validation of the general equilibrium effects of my model. I include below other relevant measurements that, though not used explicitly in this paper, are also relevant for the underlying debate of the distinction between macro and micro labor supply responses to transfers.

A small response of labor supply is also confirmed by a windfall cash transfer program held in Iran that substitutes energy subsidies and reaches more than 70 million citizens, yielding a take-up rate of about 95%. The evidence is in Salehi-Isfahani and Mostafazi-Dehzooei (2018) who analyze a rich panel of households and find no discernible negative labor supply effect, both on hours or labor force participation, with positive otucomes for women and self-employed men. In the opposite direction, a recent study by Giupponi (2018) on welfare transfers based on spouse's death uses Italian administrative data to estimate the income effect of losing the benefit. She estimates a marginal propensity to earn out of unearned income of approximately -1.0, indicating a larger response than the previously observed in the literature.

The long-term effect of transfers is estimated by Price and Song (2017) for the participants in the Seattle-Denver Income Maintenance Experiment, a program inspired by the NIT proposal. Following adults for over four decades using Social Security data, authors find that the treatment decreased earned income during the experiment, caused no significant effect immediately after it, and decreased earnings later in life. In the paper, the authors argue that the latter arises due to the interaction of a stronger preference for leisure in older ages and extra accumulated wealth. On the other hand, while further confirming the small labor supply evidence, but suggesting that it does not change at older ages, Cesarini et al. (2017) study the wealth effect of lottery prizes in Sweden. Authors find that winners slightly reduce earnings being persistent and similar by age, education, and sex.

Turning to akin settings to my quantitative model, Fabre et al. (2014) is an early work where authors compare the welfare effects of unemployment insurance (UI) against the UBI finding that the former is socially robust to the introduction of the latter. Despite drawbacks embedded in UI, such as moral hazard and government monitoring costs, the authors argue that it would take empirically implausible values for the parameters associated with these costs to make a UBI socially preferred. The main reason is that, in the mechanism proposed under incomplete markets, the UI insures agents in states of the world when they need the most. Lopez-Daneri (2016) is a key reference to our proposed framework as it studies a revenue-neutral reform of the U.S. income tax and welfare system to an NIT. The author calibrates a life-cycle model to the U.S. economy with welfare payments in a non-linear function of income and a lump-sum payment of retirement benefits. Focusing on an equilibrium with transitional dynamics for an open economy, the author finds that the optimal NIT imposes a 22% marginal tax rate and a transfer of 11% of GDP of the benchmark economy with an ex-ante welfare gain of 2.1%.

In a recent working paper, Ortigueira and Siassi (2019) develop a structural dynamic model with a rich system of means-tested, anti-poverty transfers where households make not only the standard consumption and savings decisions but also family formation and program participation. Authors find in their model that lone mothers have large incentives to work, with low-productive ones receiving, on average, a participation subsidy amounting to 15% of their labor earnings. Also, asset testing and eligibility to programs such as the SNAP or TANF introduce lsubstntial distortions in low -productive workers' savings decisions, a point discussed in detail in Wellschmied (2018). In the context of Medicaid, Pashchenko and Porapakkarm (2017) show that assets-testing can reduce labor supply distortions in an environment with unobserved productivity.

My paper adds to this literature by framing a policy scenario of a reform towards a UBI as a substitution of the IS system. Moreover, I follow Ortigueira and Siassi (2019) and Wellschmied (2018) and extend the standard modeling framework to explicitly outline the IS system and the many brackets for the different means-testing requirements in an overlapping generations economy. A novel part consists of the interaction of such a system with the operative extensive and intensive margins of labor supply modeled as in Chang et al. (2019), which yields a mechanism that allows me to understand the trade-off of both margins under the different policies. I account for human capital accumulation based on labor market experience as in Attanasio et al. (2008); Guner et al. (2019a,b); Hannusch (2019), and combine all such ingredients in a general equilibrium framework taking into account the transitional dynamics. The equilibrium component can be understood as complementary to the approach in dynamic structural models of labor supply, such as in Chan (2013), to the approach in public economics in Saez (2002); Brewer et al. (2008); Rothstein (2010), and other ones reviewed by Chan and Moffitt (2018).

As the interest in the Universal Basic Income has been sharply growing in the last few years, there is a set of recent papers that study the UBI phenomenon through different perspectives. Hanna and Olken (2018) use data from Indonesia and Peru to analyze the trade-offs involved in proxy targeting versus universal basic income. Banerjee et al. (2019) draw from the evidence of cash transfer programs in developing countries to anticipate the potential effects of a UBI as an incremental policy focused on poverty mitigation. Ghatak and Maniquet (2019) develop and study a theoretical framework to assess the normative justifications of a UBI system. Finally, and in close relation to the scope of this paper, Hoynes and Rothstein (2019) study the role of UBIs in advanced economies with a descriptive framework that encompasses different policy designs. They forecast that a UBI would direct larger transfers to childless and middle-income rather than poor households. The main contribution of this paper from the perspective of this literature is thus to add a macroeconomic framework that can serve as a quantitative laboratory to asses the impact of a nationwide reform of the welfare system and deliver precise predictions to many of the unanswered questions raised in the papers.

3 The Model

This section describes the dynamic general equilibrium model I use to analyze the macroeconomic effects of a reform of the welfare system in the U.S. towards a Universal Basic Income. The environment is a life-cycle, overlapping generations economy with incomplete markets and individual heterogeneity, endogenous labor supply, human capital accumulation, and a tax and transfers system similar to the one of the U.S.

Households are heterogeneous with respect to their age, $j \in \{1, \ldots, J\}$, permanent ability, $\theta \in \Theta$, idiosyncratic productivity shock, $z \in \mathcal{Z}$, human capital stock, $h \in \mathcal{H}$, and asset holdings $a \in \mathcal{A}$. I also model an extra degree of heterogeneity in the family structure by allowing households to differ on child-bearing as it is one of the key determinants for the allocation within the U.S. tax code, thus keeping track of whether households are child-bearers or not, $k \in \mathcal{K} = \{0, 1\}$. The state space of the economy is then the set $S = \mathcal{A} \times \mathcal{H} \times \mathcal{Z} \times \mathcal{K} \times \Theta \times \{1, \ldots, J\}$. In the subsections below, I discuss in detail every entry of the individual state space element $s = (a, h, z, k, \theta, j) \in S$.

As the environment is set with the the underlying purpose of assesing a reform of the transfer system that will be analyzed both in steady-states and along the transition, throughout the description of the model, I will selectively omit indices in order to avoid loading the notation. More specifically, I will denote all individual variables as defined over the individual state-space s, hence age-dependent and thus implicitly indexed by j. However, they should also be understood as implicitly indexed by time t. As the aggregate variables are more naturally understood to be time-dependent, I will explicitly index them by t.

3.1 Demographics

Each model period stands for one year. Time t is discrete with infinite horizon and the economy is populated by a continuum of mass one of households who live at most J years. There is uncertainty regarding the time of death in every age $j = 1, \ldots, J$ so that the household faces probability ψ_j of surviving to age j. Therefore, in every period, a fraction of the household population dies and leaves accidental bequests q. The age profile of the population $\{\mu_t\}_{j=1}^{J}$ is modeled by assuming that the fraction of households with age j in the population is given by the law of motion $\mu_j = \frac{\psi_j}{(1+g_n)}\mu_{j-1}$, that satisfies $\sum_{j=1}^{J} \mu_j = 1$, and where g_n is the population growth rate.

I assume that the household does not decide the number of children or when to have them in a similar fashion to Attanasio et al. (2008). At every period t, a fraction p_k of the households is defined to have children during their life-cycle, and are then flagged by $k = 1$. When they do so, they all have simultaneously the same number of children which solely depends exogenously on their age. Households have a number of kids $n_{k,j}$ at age j who are born in working ages $\underline{j}^i$, with $i \in I$, where I is finite. I also assume that children live in the household until they are 18 years old[3]. Given this structure, by knowing age j and the different ages when children are born $\underline{j}^i$, we can count the number of children in

[3] Here I follow the same interpretation of Attanasio et al. (2008) used in Fehr and Kindermann (2018).

the household $n_{k,j}$, as follows:

$$n_{k,j} = \sum_{i \in I} \mathbb{1} \left[\underline{j}^i \leq j \leq \underline{j}^i + 17 \right]. \tag{1}$$

Households with children pay a child-care cost η whenever they are working with any young children in the household, defined to be between zero and two years old. At the aggregate level, I define the sum of such costs as CC_t.

3.2 Preferences

Households have a time-separable period utility function, maximize their discounted expected lifetime utility from nondurable goods consumption c and labor supply l. It is defined as follows

$$\mathbb{E} \left[\sum_{j=1}^{J} \beta^{j-1} \left(\prod_{i=1}^{j} \psi_i \right) u(c,l) \right], \tag{2}$$

where β is the discount factor and $\mathbb{E}$ is the expectation operator.

3.3 Technology

There is a single good produced in this economy with technology given by a Cobb-Douglas production function that exhibits constant returns to scale, $Y = F(K_t, L_t) = K_t^{\alpha}(Z_t L_t)^{1-\alpha}$, where $\alpha \in (0,1)$ is the output share of capital income and Y_t, K_t and L_t denote, respectively, aggregate output, physical capital and labor. The final good can be consumed or invested in physical capital on a one-to-one basis.

The price of the consumption good is normalized to one and aggregate investment in physical capital, I_t, is defined by the following law of motion:

$$K_{t+1} = (1 - \delta_k)K_t + I_t, \tag{3}$$

where δ_k is the depreciation rate of physical capital.

This technology is used by a representative firm that behaves competitively maximizing profits at every period t by choosing labor and capital given factor prices. The profit maximization problem is:

$$\Pi_t = \max_{K_t, L_t} K_t^{\alpha} L_t^{1-\alpha} - w_t L_t - (r_t + \delta_k) K_t. \tag{4}$$

which yields the following first-order conditions:

$$r_t = \alpha \left(\frac{K_t}{L_t} \right)^{\alpha - 1} - \delta_k \tag{5}$$

$$w_t = (1 - \alpha) \left(\frac{K_t}{L_t} \right)^{\alpha} \tag{6}$$

3.4 Endowments and Labor Income

Agents are born with zero assets, endowed with one unit of time, and forcefully retire at age J_R. While working, individual wage depends on the competitive wage w_t, a permanent ability shock $\theta \sim N(0, \sigma_\theta^2)$, human capital level h_j, and an idiosyncratic persistent shock z_j.

I assume that households can only choose their hours within the set $[0, 1]$ and are subject to a non-convexity associated with set-up costs for work - such as commuting time - as in Chang et al. (2019). I define then $\ell(l)$ to be the effective hours of work and use the following functional form to account for this effect:

$$\ell(l) = \max \left\{ 0, l - \bar{l} \right\}, \; l \in [0, 1], \tag{7}$$

where l is the individual labor supply and $0 < \bar{l} < 1$.

The function in (7) above imposes a wedge in the mapping between chosen hours and labor earnings and it gives rise to adjustments along the extensive and intensive margins as in Prescott et al. (2009). It can also be understood in the same fashion as the non-linearity of such mapping in Erosa et al. (2016).

Moreover, this formulation is particularly suited to the nature of this paper's question, which calls for precise predictions about the behavior of the labor supply and allows sharp distinctions between participation and movements through part-time and full-time work[4]. This characterization is useful later in the validation of the model in section 5.3.

Households pre-tax labor income is then defined by:

$$y(l, h_j, z_j) = \quad w \cdot \exp(\theta) \cdot \exp(z_j) \cdot h_j \cdot \ell(l) \tag{8}$$

I follow the approach used in Attanasio et al. (2008) and Guner et al. (2019a,b) and assume that the human capital component evolves according to a law of motion that takes into account the increasing return on wage due to labor market experience:

$$h_{j+1} = H(h_j, l, j; \nu, \delta_h) = \exp\left[\ln h_j + (\nu_1 + \nu_2 \cdot j)\, \mathbb{1}_{[l_j>0]} - \delta_h \left(1 - \mathbb{1}_{[l_j>0]}\right)\right] \tag{9}$$

where ν_1 captures the positive effect of working, ν_2 is the diminishing marginal return of the incremental year in the labor force, and δ_h stands for the depreciation rate of the human capital stock when out of the labor force[5]. I define the aggregate level of human capital by HC_t. The idiosyncratic component z_j follows an AR(1) process defined by :

$$z_{j+1} = \rho z_j + \varepsilon_j,\ \varepsilon_j \sim N(0, \sigma^2_\varepsilon) \tag{10}$$

[4]As emphasized in Chang et al. (2019), in this setting, adjustments along the intensive margin generate larger increases in efficiency units than those along the extensive margin. Due to this, I report, among other relevant moments, the mean aggregate efficiency units of labor.

[5]Here, I also follow the interpretation used in Fehr and Kindermann (2018).

which is discretized in a Markov chain with transition matrix $\pi_{z,z'} = \Pr(z_{j+1} = z' | z_j = z)$ and stationary distribution $\Pi(z)$.

From age J_R and onwards labour supply is forcefully zero and agents live off potential transfers, retirement benefits and accumulated wealth. I also assume that there is no altruistic bequest motive and there is the certainty of death at $J+1$. Hence, agents alive at age J consume all resources, implying $a_{J+1} = 0$.

3.5 Government

The government runs a welfare system designed to mimic the one of the U.S. economy, has pure public spending G_t, payments of its debt stock B_t, and collect taxes from households to finance it. I assume that both spending and public debt are defined by exogenous and constant shares of Y_t given by b_G and b_B, respectively.

The revenue to finance welfare and spendings is levied by an exogenous tax rate on capital income, τ_r, a non-linear, exogenous, and progressive tax schedule on labor income, $T_l(y)$, and an endogenous tax rate on consumption $\tau_{c,t}$ that adjusts to balance the government budget. Finally, an endogenous payroll tax rate $\tau_{SS,t}$ separately balances the budget of the Social Security system.

The labor income tax function is given by $T_l(y) = y_j - \tau_0 y^{(1-\tau_1)}$, where τ_0 is the scale parameter that defines the level of the average tax rate and τ_1 is the parameter that governs the degree of progressivity implied by the curvature of the function. This formulation was initially used in Benabou (2002) and has recently become the benchmark in the literature measuring the impact of top-income taxation in government revenue in general equilibrium economies with heterogeneous agents (Guner et al., 2016; Heathcote et al., 2017; Holter et al., 2019). I denote by TL_t the aggregate level of labor income tax collected.

The Income Security system (IS) is composed of the Earned Income Tax Credit (EITC), other means-tested cash transfers such as the Suplemental Nutrition Assistance Program (SNAP) or the Temporary Assistance for Needy Families (TANF), and the Supplemental Security Income (SSI), available only when agents retire. I model the brackets and testing details of the EITC exactly as defined by the *Internal Revenue Services* (IRS) by following the formulations in Ortigueira and Siassi (2019), and use a simplified way modelling of the SNAP and TANF programs for tractability purposes in a similar fashion to Wellschmied (2018). The SSI is modeled as defined by the U.S. *Social Security Administration* (SSA).

First, it is helpful to lay out key definitions used in the characterization of the transfer programs. Total labor income $y(l, h_j, z_j)$ will henceforth stand for *gross income* and $d = ra$ for *investment income*. I also need to define *gross adjusted income* as $y_a \equiv y(l, h_j, z_j) + d$. The EITC is a refundable credit in which the eligibility is determined by two criteria: first, investment income cannot exceed a level $\bar{d}_{TC}$ and second, gross adjusted income cannot be higher than an upper bound $\bar{y}^k_{TC}$ which depends on the number of children $n_{k,j}$ present in the household. As it is defined as a percentage of positive labor income y, it is, in essence, a work subsidy. The payment structure is composed by three parts: a phase-in region, a so-called plateau region, and a subsequent phase-out region.

The individual level of transfers for the EITC is defined as T_{TC} and the overall structure is summarized as follows:

$$T_{TC}[y, d, j] = \begin{cases} \kappa_1^k y, & \text{if } 0 \leq y < \underline{y}^k \\ \kappa_1^k \underline{y}^k, & \text{if } \underline{y}^k \leq y < \bar{y}^k \\ \max\{\kappa_1^k \underline{y}^k - \kappa_2^k (y - \bar{y}^k)\}, & y > \bar{y}^k \\ 0, & \text{if } d > \bar{d}_{TC} \text{ or } y_a > \bar{y}^k_{TC} \text{ or } j \geq J_R \end{cases} \tag{11}$$

where κ_1^k and κ_2^k are the phase-in and phase-out rates, respectively, and $\underline{y}^k$ and $\bar{y}^k$ are the income thresholds for the plateau. Note that all brackets are indexed by k, which stands for the dependance on the number of children $n_{k,j}$. The investment eligibility requirement, on the other hand, is invariant to such number. I define the total aggregate level of transfers paid via the EITC by TTC_t, standing for *total tax credit*.

I model the other means-tested cash transfer programs in a similar fashion, with the difference that now thresholds are on households' asset holdings and adjusted income, as it is defined in the tax code for both the SNAP and the TANF. The SSI, given the absence of labor income during retirement, is only tested for households' asset level. I denote thie maximum level of assets for both the TANF and the SNAP as $\bar{a}_{CT}$, and the maximum level of adjusted income for the SNAP as $\bar{y}_{CT}$. I abstract from all other qualitative requirements for eligibility regarding family size or co-habitation of parents for households with children as well as the tapering in their phase-out brackets.

The payment schedule for the individual level of transfers T_{CT} for such programs is thus defined below:

$$T_{CT}[y_a, a, j] = \begin{cases} t_{SNAP}, & \text{if } a \leq \bar{a}_{CT} \text{ and } y_a \leq \bar{y}_{CT} \text{ and } j < J_R \\ t_{SSI}, & \text{if } a \leq \bar{a}_{SSI} \text{ and } j \geq J_R \\ 0, & \text{otherwise} \end{cases} \tag{12}$$

where t_{SNAP} and t_{SSI} are the transfer values. I denote the total aggregate level of cash transfers by TCT_t, standing for *total cash transfers*. The total expenditure of the government on means-tested cash transfers is then defined as the sum $TR_t = TTC_t + TCT_t$.

The SS system is operated in a pay-as-you-go schedule. It is balanced by a payroll tax rate $\tau_{SS,t}$ and pays retirement benefits independent of individuals' history defined by $b(x_t) = b_{SS}x_t$, where b_{SS} is the replacement rate and x_t is the average level of labor earnings of period $t-1$, normalized by the measure of working households.

At last, I also assume that the government is responsible for collecting all accidental bequests q_j, denoted by Q_t when at the aggregate level. Hence, at any time t the budget of the tax system is balanced if, and only if,

$$G_t + (1 + r_t)B_t + TR_t = \tau_{c,t}C_t + TL_t + \tau_r r_t A_t + Q_t + (1 + g_n)B_{t+1}. \tag{13}$$

Here we have that, in the aggregate, the transition path is characterized by several time-dependent endogenous objects, including the government's debt. This formulation follows the one in Kindermann and Krueger (2018) and, by assumption, the govenment does not run fiscal deficits to ensure satisfaction of its budget constraint.

3.6 Recursive Household Problem

Let $v(s)$ denote the value function of a j year old agent. As defined previously, $s = (a, h, z, k, \theta, j) \in S$ is the individual state space. Also, let $v^R(s)$ for $j = J_R, \ldots, J$ denote the value function of an individual aged j who is retired and receives Social Security benefits. I normalize the value function of the terminal age J to zero, $v^R(s_{-j}, J+1) = 0$, where henceforth s_{-j} stands for the individual state-space without the age dimension.

The problem of an agent with age $j = 1, \ldots, J_R - 1$ that lies inside the fraction p_k of the population that bears children in their life-cycle is represented in the recursive form in the Bellman equation (14) below. For the agents inside the fraction $(1 - p_k)$, the definition is identical with $k = 0$, $\forall j$.

$$
\begin{aligned}
&v(a,h,z;k=1,\theta,j) = \max_{c,a',l} u(c,l) + \beta\psi_{j+1}\mathbb{E}_z\left[v(a',h',z';k=1,\theta,j+1)\right] \\
&\text{s.t.} \\
&(1+\tau_c)c + a' + \eta\mathbb{1}_{\left[l>\bar{l},\,(j-\underline{j}^i)\leq 2\right]} = a(1+r(1-\tau_r)) + (1-\tau_{SS})y(l,h,z) \\
&\qquad\qquad - T_l[y(l,h,z)] + T_{TC}[y(l,h,z),d,j] + T_{CT}[y_a,a,j] \\
&\quad y(l,h,z) = w\exp(z+\theta)h\ell(l), \quad h' = H(h,l,j;\nu,\delta_h) \\
&\qquad\qquad n_{k,j+1} = \sum_{i\in I}\mathbb{1}\left[\underline{j}^i \leq j+1 \leq \underline{j}^i + 17\right] \\
&\qquad c > 0, \qquad a' \geq 0, \qquad 0 \leq l \leq 1
\end{aligned}
\tag{14}
$$

For individuals at ages $j = J_R, \ldots, J$ the problem is:

$$
\begin{aligned}
&v^R(a,j) = \max_{c,a'} u(c,0) + \beta\psi_{j+1}v^R(a',j+1) \\
&\text{s.t.} \\
&(1+\tau_c)c + a' = a(1+r(1-\tau_r)) + b(x) + T_{CT}[0,a,j] \\
&\qquad\qquad c > 0, \quad a' \geq 0
\end{aligned}
\tag{15}
$$

The solution of the dynamic programs (14) and (15) provides us the decision rules for the asset holdings $a : S \to \mathbb{R}_+$, consumption $c : S \to \mathbb{R}_{++}$, and labour supply $l : S \to [0,1]$.

3.7 Equilibrium

Agents are heterogeneous at each point in time in the state $s \in S$. The agents' distribution among the states s is described by a measure of probability Φ_t defined on subsets of the state space S. Let $(S, \mathcal{B}(S), \Phi_t)$ be a space of probability, where $\mathcal{B}(S)$ is the Borel σ-algebra on S. For each $\omega \subset \mathcal{B}(S)$, $\Phi_t(\omega)$ denotes the fraction of agents that are in probability state ω. There is a transition function $M_t(s, \omega)$ which governs the movement over the state space from time t to time $t+1$ and that depends on the invariant probability distribution of the idiosyncratic shock $\Pi(z)$ and on the decision rules obtained from the household's problem.

The definition below stands for the recursive competitive equilibrium. The definition for the stationary equilibrium can be found in Section D of the Appendix.

Definition 1 (Recursive Competitive Equilibrium)**.** *A recursive competitive equilibrium with population growth for this economy is an allocation of value functions* $\{v_t(s), v_t^R(s)\}_{t=0}^{\infty}$*, policy functions* $\{c_t(s), a_t'(s), l_t(s)\}_{t=0}^{\infty}$*, prices* $\{w_t, r_t\}_{t=0}^{\infty}$*, productions plans for the firm* $\{K_t, L_t\}_{t=0}^{\infty}$*, consumption taxes* $\{\tau_{c,t}\}_{t=0}^{\infty}$*, social security taxes and benefits* $\{\tau_{SS,t}, b(x_t)\}_{t=0}^{\infty}$*, aggregate transfers* $\{TR_t\}_{t=0}^{\infty}$*, government expenditures and debt* $\{G_t, B_t\}_{t=0}^{\infty}$*, accidental bequests* $\{Q_t\}_{t=0}^{\infty}$*, and age-dependent measure of agents* $\{\Phi_t\}_{t=0}^{\infty}$*, such that,* $\forall t$*:*

1. *Given factor prices, taxes and transfers, and initial conditions, the value functions* $\{v_t(s), v_t^R(s)\}$ *and policy functions* $\{a_t'(s), c_t(s), l_t(s)\}$ *solve the households' optimization problems (14) and (15);*

2. *The individual and aggregate behaviours are consistent:*

$$G_t = g_y Y_t, \;\; B_t = g_b Y_t$$

$$(1+g_n)K_{t+1} = \int_S a_t'(s) d\Phi_t(s) - (1+g_n)B_{t+1}$$

$$C_t = \int_S c_t(s) d\Phi_t(s)$$

$$L_t = \int_S y(l_t(s), h, z) d\Phi_t \left(s_{-j}, \{1, \ldots, J_R - 1\}\right)$$

3. *$\{r_t, w_t\}$ are such that they satisfy the firm's first-order conditions (5) and (6);*

4. *The final good market clears:*

$$C_t + K_{t+1} + G_t + CC_t = AK_t^{\alpha} L_t^{1-\alpha} + (1 - \delta_k) K_t$$

5. *The Government balances its budget:*

$$G_t + \int_S \left[T_{TC,t}(s) + T_{CT,t}(s)\right] d\Phi_t(s) + (1 + r_t) B_t =$$
$$\int_S \left[\tau_r r_t a_t(s) + \tau_{c,t} c_t(s) + \left(y_t(s) - \tau_0 y_t(s)^{(1-\tau_1)}\right)\right] d\Phi_t(s) + Q_t$$

6. *Social Security's budget balances:*

$$\tau_{SS,t} w_t L_t = \int_S b(x_t) d\Phi_t \left(s_{-j}, \{J_R, \ldots, J\}\right)$$

7. *Accidental bequests equals the savings left from deceased households:*

$$Q_t = \int_S (1 - \psi_{j+1}) a_t'(s)\, d\Phi_t(s)$$

8. *Given the decision rules, Φ_t satisfies:*

$$\Phi_{t+1}(\omega) = \int_S M_t(s, \omega) d\Phi_t(s),\ \forall \omega \subset \mathcal{B}(S),$$

where $M_t : (S, \mathcal{B}(S)) \to (S, \mathcal{B}(S))$, can be written as folllows: $\forall j \in \{2, \ldots, J\}$,

$$M_t(s, \omega) = \begin{cases} \pi_{z,z'} \cdot \psi_{j+1}\,, \ \textit{if}\ \ a'(s) \in \mathcal{A},\ h'(s) \in \mathcal{H},\ k \in \mathcal{K},\ \theta \in \Theta,\ j+1 \in \{2, \ldots, J\} \\ 0\ ,\ \textit{otherwise.} \end{cases}$$

and for $j \in \{1\}$,

$$\Phi_{t+1}\left(S_{-J}, 1\right) = (1+g_n)^t \begin{cases} \sum\limits_{k\in\mathcal{K},\theta\in\Theta} p_k \cdot p_\theta\,, & \textit{if } 0 \in \mathcal{A},\ h_0 \in \mathcal{H},\ \bar{z} \in \mathcal{Z} \\ 0\,, \textit{otherwise}, \end{cases}$$

where p_k *and* p_θ *are, respectively, the probabilities of being a household with children and of drawing* θ *out of its discretized distribution. The initial conditions are* $a_0 = 0$, $h_0 = 1$, *and* $\bar{z}$, *the average level of productivity.*

4 Calibration

4.1 Demographics

In the model agents are born at $j = 1$ which stands for age 20 in real life, start their retirement at age $J_R = 45$, standing for 65 in real life, and die with probability one at age $J = 80$, equivalent to 100 years old. The age-dependent survival probabilities $\{\psi_j\}_{j=1}^{J}$ are the ones estimated by Fehr and Kindermann (2018) for the U.S. population in 2010. The population growth is set to be $g_n = 1.1\%$, the average long run value for the US. I set the fraction of households that will have children during their lifespan to $p_k = 30\%$. They will have three children born at ages $\underline{j}^i = \{27, 30, 33\}$, being then $I = \{1, 2, 3\}$ in equation (1) that defines the number of children at age j, $n_{k,j}$ (Fehr and Kindermann, 2018). The number of children is set to a maximum of 3 due to the design of the EITC as defined by the IRS. More details are discussed in Appendix C.

4.2 Preferences

The period utility is

$$u(c, l) = \log(c) - \varphi \frac{l^{1+\frac{1}{\gamma}}}{1+\frac{1}{\gamma}} \tag{16}$$

where φ controls intensity of labor vs. consumption, γ governs the Frisch elasticity. Preferences are in King-Plosser-Rebelo form and are consistent with a balanced growth path.

I set $\gamma = 1$ as in Lopez-Daneri (2016). I jointly and endogenously calibrate φ and $\bar{l}$, so that the aggregate average hours dedicated to work are a third of household's unit endowment of time $H = 33\%$ and the Labor Force Participation rate (LFP) is 70%. The first number is standard in the literature and the second one is calculated by the *Bureau of Labor Statistics* (BLS) using the *Current Population Survey* (CPS) for males older than 16 in 2018[6]. Finally, I endogenously calibrate the time discount factor β to match a capital-output ratio of $K/Y = 2.9$, as in Kindermann and Krueger (2018).

4.3 Technology

I set the capital share of the economy to be $\alpha = 35\%$ as in Lopez-Daneri (2016), which is the average in the U.S. between 1960-2007. I calibrate the depreciation rate of capital δ_k so that the benchmark steady-state real interest rate is $r = 4\%$.

4.4 Labor Income

As mentioned above, I calibrate the parameter $\bar{l}$ governing the wedge between hours and earnings jointly with φ to match average hours and the LFP rates. The variance for the permanent ability shock is calibrated to be $\sigma_\theta^2 = 0.5212$ in order to target the Gini index of the earnings distribution. The bend points $\{\nu_1, \nu_2\}$ for the returns to experience in the human capital law of motion are taken from the coefficients estimated in the Mincerian

[6] The table can be found in this link.

regression given by equation (20) shown in the Appendix. As the third coefficient of the cubic polynomial is of a small order of magnitude and has a less straightforward economic interpretation, I consider only the first two. The depreciation of human capital is taken from the value estimated in Guvenen et al. (2014) and thus set to $\delta_h = 1.5\%$.

If households have kids with age $j^i \in \{0, 1, 2\}$ in the household, they pay childcare cost $\eta = 0.069$ whenever they have positive labor supply. This value is calibrated to target childcare costs standing for 11% of the average household income. The number is taken from the 2018 report "The US and the High Cost of Child Care" released by *Child Care Aware of America*[7] and stands for the average level of the share of earnings paid by married couples based on different methodology of calculations that take into account the main stages of childhood. Finally, the persistence ρ and the error variance σ_ε^2 are the ones obtained by the estimation of the income process from the SIPP 2008. I use the point estimates obtained with the identity matrix as the GMM weighting matrix. The methodology is described in the Appendix and depicted in Table 18.

4.5 Government

I follow Holter et al. (2019) and choose the fractions $b_G = 7.25\%$ and $b_B = 61.85\%$ such that the value of pure public consumption, G, is equal to two times the military spending and that the outstanding government debt, B, in the model is equal to US's debt-to-GDP ratio.

On the taxation side, I calibrate the capital income tax rate as $\tau_r = 7.4\%$ as in Lopez-Daneri (2016). I set the parameters governing the progressive income tax function as in Holter et al. (2019), where they use OECD tax data to find the values for married couples in the US. That yields scale parameter $\tau_0 = 0.9420$ and curvature $\tau_1 = 0.1577$. Finally, the payroll contribution rate of the Social Security system, τ_{SS}, is calibrated endogenously to target areplacement rate $b_{SS} = 36\%$. This is the median rate calculated by the CBO based on either the highest 35 years of earnings or the last 5 years of substantial earnings. It is the number calculated for both sexes and including all quintiles of the earnings distribu-

[7] The report can be found in this link.

tion[8]. As mentioned previously, the tax on consumption τ_c is the endogenous equilibrium outcome that balances the government budget.

I follow an approach based on Ortigueira and Siassi (2019) and Birinci (2019) to guide the way I discipline the choice of relative magnitudes between the parameters, brackets, and transfers sizes based on the transfers code that characterize the IS programs and model units. As there are several parameters, values, and references to documentation, I explain it all in detail in Appendix C.

4.6 Summary of Calibration

I summarize the information associated with the calibrated parameters in the sequence of tables below. In Table 1, one can find the exogenously calibrated parameters and their sources. Table 2 shows the endogenously calibrated parameters, the targeted moments associated with each of them, and the source of such moments for their data counterparts. Finally, in another set of tables in the Appendix, I display all the parameters and values used in the model economy's Income Security system. Table 19 and 20 collects the EITC parameters. In Tables 21 and 22 one can find the parameters for the remaining IS programs.

[8] More details can be found in the report via this link.

Table 1: Exogenously calibrated parameters.

	Parameter	Value	Target / Source
Demographics			
Model's terminal and retirement ages	JJ, J_R	80, 45	Ages 100 and 65
Population growth	n_p	1.1%	Historical data
Survival probabilities	$\{\psi_j\}_{j=1}^{J}$	-	Fehr and Kindermann (2018)
Ages children are born	$\{n_i\}_{i=1}^{3}$	27, 30, 33	Exogenous
Fraction of pop. with children	p_k	30%	Bureau of Labor Statistics
Preferences			
Frisch elasticity	γ	1.00	Lopez-Daneri (2016)
Technology			
Capital share	α	0.35	Historical data
Labor Income			
Persistence and variance of AR(1)	$\{\rho, \sigma_\varepsilon^2\}$	0.9342, 0.0176	SIPP 2008
Human capital returns	$\{\nu_1, \nu_2\}$	0.0533, -0.0013	SIPP 2008
Depreciation rate of human capital	δ_h	1.5%	Guvenen et al. (2014)
Government			
Public consumption goods, national debt	$\{b_G, b_B\}$	7.25%, 61.85%	Holter et al. (2019)
Investment income tax rate	τ_r	7.4%	Lopez-Daneri (2016)
Scale and curvature of income taxes	$\{\tau_0, \tau_1\}$	0.9420, 0.1577	Holter et al. (2019)

Table 2: Endogenously calibrated parameters.

	Parameter	Value	Target	Source
Preferences				
Discount factor	β	0.981	$K/Y = 2.9$	Kindermann and Krueger (2018)
Disutility of labor	φ	12.650	H = 33%	Standard
Commuting costs	$\bar{l}$	0.158	LFP = 70%	Bureau of Labor Statistics
Labor Income				
Childcare cost	η	0.068	11% of $\bar{y}$	Child Care Aware of America
Variance of permanent shocks	σ_θ^2	0.521	Earn. Gini = 0.44	SIPP 2008
Technology				
K depreciation rate	δ_k	7.8%	r^* = 4%	Standard
Government				
SS Payroll tax	τ_{SS}	10.61%	b_{SS} = 36%	Congressional Budget Office

5 The Benchmark Economy

5.1 Aggregates

I begin the assessment of the benchmark economy by reporting the equilibrium quantities of the main aggregate variables of the model and comparing them to their counterpart targeted and non-targeted levels in the data. Table 3 below summarizes the moments of the benchmark model with the baseline welfare system composed of the means-tested transfers. The model matches closely the aggregate levels of interest. The capital-to-ouput ratio, K/Y, the aggregate level of hours worked, H, the equilibrium interest rate, r, and the labor force participation (LFP) are all at their targeted levels. The investment-to-GDP ratio, I/Y, and the consumption-to-GDP ratio, C/Y, were not targeted but are both at levels coherent with the historical US data.

As I target the replacement rate of the SS system, b_{SS}, the payroll tax used to close the system's budget endogenously achieves the rate of 10.61%, which is thus non-targeted and close to the 12.4% rate set by the IRS. A similar pattern applies to the endogenous tax on consumption, τ_c, with the difference that the US does not have such tax at the federal level. Nonetheless, the value obtained of 8.1% is not far from the level estimated in Trabandt and Uhlig (2011), and this rate provides an estimate of the tax burden of the benchmark income security system to provide aggregate level of transfers TR, which is key in the counterfactual comparisons.

Table 3: Aggregate variables.

Variable	Benchmark	Target / Data	Source
Targeted			
K/Y	290.0%	290%	Standard
H	33.1%	33%	Standard
LFP	69.3%	70%	BLS
r	0.042	0.04	-
Untargeted			
C/Y	64.2%	68%	FRED
I/Y	25.5%	17%	FRED
TR/Y	3.8%	1.3%	CBO
τ_c	8.1%	5%	Trabandt and Uhlig (2011)
τ_{SS}	10.6%	12.4%	IRS

Note: The data counterparts shown in the table are taken from several sources. I use the last available period of FRED St. Louis data for share of personal consumption expenditures over GDP, and gross private domestic investment over GDP. It can be found, respectively, in the following links: here, and here. The CBO data stands for the breakdown of mandatory spending in 2018 and can be found here. The SS withtholding rate is defined by the IRS and can be found here.

5.2 Earnings and Wealth Distributions

The evaluation of the model fit is also depends on the comparison of the inequality on labor earnings and wealth in the benchmark economy with the one observed in the data. Table 4 below shows such distributional outcomes of the model in comparison with the SIPP 2008 estimates, all of those untargeted moments, except, as mentioned previously, for the Gini coefficient of the labor earnings distribution.

The model is able to closely approximate the earnings distribution, with some overstatement in the fourth quintiles and understatement of the top quintile. Given that we have estimated the wage process directly from our sample of the SIPP data and exogenously fed into the model this source of earnings risk, such positive result is expected. However, the close fit in terms of magnitude in all quintiles is reassuring that the labor income side of the baseline economy is able to exhibit similar behavior to the data.

A second and more rigorous assesment of the fit can be done by observing the wealth distribution outcomes. As the savings decisions is one of the critical endogenous choices of the agents in the model, their behavior in terms of savings gives us a more accurate understanding on whether the environment of the benchmark economy captures correctly the mechanism behind such decision in the data. The model is able to quantify well the share of wealth accruing to almost all quintiles, understating by 6 percentage points the top quintile and overstating by 5 percentage points the second top. The Gini coefficient matches closely the one calculated in the data.

As it is well-known in Bewley-Huggett-Aiyagari-Imrohoroglu economies, it is a challenge for such models to capture the very top of the wealth distribution, often requiring elements in the environment to allow for that match, such as the presence of entrepreneurs or "superstars". As the objective of this study is mostly to focus on the bottom of the distribution, I have refrained from adding such elements, therefore yielding the aforementioned understatement at the top.

At very bottom of the wealth distribution, as the model does not allow borrowing, the distribution stops at zero assets. It is not able then to capture the negative value standing for debt, as observed in the data for the first quintile. However, the model is overall able to capture a low level of savings for the first three quintiles, approximating well the distribution computed in the data, and also close to the one calculated using other surveys such as the *Survey of Consumer Finances* (SCF) or the *Panel Study of Income Dynamics* (PSID) (Kuhn and Rios-Rull, 2015; Krueger et al., 2017). This outcome is mainly possible due to a combination of two model ingredients: the steep profile in earnings generated by the human capital accumulation component and the different levels of assets and investment income testing that the IS system imposes to agents in the economy.

The intuition behind this outcome comes from the fact that households are born with zero assets and then climb up the savings ladder as they receive the idiosyncratic shocks. The shocks are persistent and households that receive low level shocks end up always preferring to choose a smaller level of assets in order to frontload consumption when incentive to work are small. This consumption-savings trade-off is further enhanced by the presence of means-tested transfers. This point is developed again later, when I highlight the distortions induced by the means-testing vis-a-vis the the UBI [9].

Table 4: Earnings and wealth distribution.

	Earnings		**Wealth**	
	Data	Model	Data	Model
Quantile				
Bottom 20%	3.7%	3.6%	-0.7%	0.0%
20% - 40%	9.1%	7.9%	1.8%	0.8%
40% - 60%	15.0%	15.8%	7.7%	9.3%
60% - 80%	23.4%	25.5%	20.5%	25.5%
80% - 100%	48.7%	47.1%	70.7%	64.3%
Gini	0.44	0.44	0.70	0.69

Note: The data counterparts shown in the table are all taken from my own calculations from the SIPP 2008 panel. A more detailed description can be found in the Section A of the Appendix.

5.3 The Alaska Permanent Fund Dividend

A final step taken towards evaluating the model fit consists of checking whether the predicted behavior of the model economy aggregates are in accordance with the empirical evidence of the effects of unconditional transfers on the labor side of the economy. In order to do so, I will compare the outcomes of the model to some of the estimates of Jones and Marinescu (2018) for the impact of the Alaska Permanent Fund Dividend. As mentioned before, the Alaska's experience is by now the closest we can get in terms of empirical evidence to an understanding of the macroeconomic and general equilibrium impact of unconditional transfers.

The idea behind this validation is to operate the following thought experiment: we

[9] Such low wealth accumulation due to assets means-testing has a similar mechanism to the one pointed in Hubbard et al. (1995) and re-emphasized in Wellschmied (2018).

start with the economy at the initial steady-state with the means-tested transfer system and then move to a counterfactial economy where all households receive the dividend. The structure of benefits is maintained intact, and thus the dividend is just an addition on top of the currently existing benefits. This extra expenditure in the government's budget constraint is funded by windfall revenues and thus there is no need for the adjustment of taxes to keep the government budget constraint balanced. The size of the transfer distributed to each of the households is the equivalent of US $1,115 in model units, which is the average dividend level from 1982 to 2018[10]. This yields a transfer of 1.9% of the GDP per capita in the model economy.

In the first row of Table 5 below, I show the relevant point estimates taken from Jones and Marinescu (2018). The first column shows the difference in the average employment rate between Alaska and their controlled sample. This is the evidence that highlights the adjustment of the extensive margin of labor and shows virtually zero effects with a point estimate of -0.001. In the second column, I move to one of their measures of adjust ment at the intensive margin, which is the part-time rate (part-time employment as a share of the population). They estimate an aggregate increase of 1.8 percentage points between treatment and control averages.

In the second and third rows of Table 5, I show the differences in model averages between the benchmark and counterfactual economies. Moreover, in order to highlight the role of general equilibrium effects and how the adjustment of aggregate demand and supply of labor in the economy brings the model behavior closer to the data, I report both partal and general equilibrium results.

It is also worth to notice that the results for the part-time rate require a mapping of this definition in terms of the model economy. As in Jones and Marinescu (2018) the main data source is the *Current Population Survey* (CPS), part-time employment is defined as less than 35 hours of work per week. As labor supply in the model is defined in terms of percentage of the unit endowment of time of households, part-time is then approximately the use of 29% or less of their endowment when compared to a full-time work week.

[10]The table with the historical data of the dividend is provided by the *Alaska Department of Revenue - Permanent Fund Dividend Division* and can be found in this link.

Given that the model has the non-convex mapping between hours and earnings defined in equation (7), it exhibits a continuous intensive margin that allows for this notion to be well-defined in terms of the model labor supply allocations.

The results in Table 5 show that the model is able to replicate both the signs and the order of magnitude of the changes in the average employment rate and the average part-time rate. Moreover, the general equilibirum component is crucial for the model not to overstate such changes. In fact, for the employment rate, the availability of windfall transfers for the households dampens their extensive margin, yielding a drop at the employment rate which is attenuated once the general equilibrium effect is added. The decrease in the labor supply is followed by the adjustment in the competitive wage, which increases, thus pushing labor supply to increase back, diminishing the net effect on the employment rate. A similar intuition applies to the movement in the part-time rate. As more transfers are available, households can now operate in their intensive margin, increasing leisure and thus the part-time rate. Given that the price of labor adjusts to this movement, incentives to work more grow, and the part-time rate falls accordingly.

Table 5: Estimated differences between treatment and control for Alaska.

	Differences of Averages	
	Employment Rate	**Part-time Rate**
Data	-0.001	0.018
Model - Partial Equilibrium	-0.004	0.026
Model - General Equilibrium	-0.001	0.023

Note: The row for data show the estimates obtained in Jones and Marinescu (2018). The rows for the model shows diferences between model aggregates in the benchmark and counterfactual economies.

6 Quantitative Exercises

In this section I outline the results of the quantitative exercises conducted highlighting the impacts on aggregates, life-cycle profiles, and inequality. In section 6.1, I discuss the thought experiment behind the expenditure-neutral UBI counterfactual, its results and the mechanism behind the economies with and without means-testing. In section 6.2, I then move to a UBI reform with a level of US$12,000 annualy. In sections 6.3 and 6.4, I discuss, respectively, the impact of both reforms on inequality and the government budget constraint.

6.1 Expenditure-neutral UBI

The idea behind the counterfactual towards a UBI reform of the Income Security system is simple: substitute all transfers $T_{TC}[y,d,j]$ and $T_{CT}[y_a,a,j]$ defined in (11) and (12) with an unconditional payment TR_{UBI}. I hold constant the commitment on spending and debt level, $G = b_G Y$, $B = b_B Y$, and distribute to the households the same aggregate level of total transfers TR computed for the benchmark equilibrium in a per household base. The budget constraint of the household then becomes:

$$\text{if } j < J_r : \quad (1+\tau_c)c + a' + \eta \mathbb{1}_{[l>\bar{l}]} = a(1+r(1-\tau_r)) + (1-\tau_{SS})y(l,h,z) - T_l[y(l,h,z)] + TR_{UBI} \tag{17}$$

$$\text{if } j \geq J_r : \quad (1+\tau_c)c + a' = a(1+r(1-\tau_r)) + b(x) + TR_{UBI} \tag{18}$$

The government budget balance remains being financed with consumption taxes - i.e., with τ_c endogenously changing - and equation (13) holds in the same way with the substitution of TR by TR_{UBI}. These transfers have the same exact numerical value in this expenditure-neutral exercise.

6.1.1 Aggregates

In Table 6 below, I summarize the aggregate changes generated by the counterfactual exercise in comparison with the benchmark scenario. With respect to the labor supply response, the impact on aggregate hours is moderate, with the overall level climbing to about 1 percentage point higher than the one in the benchmark. This happens because, in the counterfactual economy, households no longer need to adjust their intensive margin downwards to fall inside the means-testing brackets. The UBI mostly operates via the income effect, shown by the movement at the extensive margin which decreases the labor force participation by one percentage point.

One can also observe the impact of the reform on the budget captured by τ_c, which is now slightly smaller than the benchmark level due to the decrease in TR/Y. I explore this point further and in convolution witht the distirbutional outcomes in the breakdown of the government constraint in 6.4. The capital-output ratio is larger in the UBI economy, mainly driven by the increase in savings and yielding higher levels of capital, which then pushes the increase in the output level.

The aggregate stock of human capital in relation to output, HC/Y, decreases by ten percentage points due to the decrease in the number of participants in the labor force, without significant large participation of high productivity households. Following the small levels of movement in L, the impact on labor earnings inequality is small, while there is a significant increase on wealth inequality, which mostly stems from the accumulation of capital by agents that receive high and persistent labor income shocks and thus are the driving force behind the capital stock increase.

Table 6: Comparison of aggregates.

Variable	**Means-Tested**	**UBI**
Y	100	105.2
K	100	110.7
L	100	102.3
C	100	103.2
HC	100	99.9
H	33.1%	34.4%
LFP	69.3%	68.6%
K/Y	290.0%	305.2%
C/Y	64.2%	63.1%
L/Y	56.3%	54.8%
HC/Y	288.1%	273.6%
TR/Y	3.8%	3.6%
w	1.153	1.185
r	0.042	0.036
τ_c	8.1%	7.8%
Earnings Gini	0.42	0.46
Wealth Gini	0.69	0.77

Note: The column with name "Means-Tested" shows the results of the benchmark model and the column with label "UBI" shows the results for the counterfactual exercise.

6.1.2 The Mechanism

In order to understand the mechanism behind the movements shown in the aggregate effects, I explore below the sources of distortions arising from the different types of means-testings in the model. I do so for select parts of the state-space that are chosen to highlight where such testings are more salient.

In Figure 1 below, I show the assets' policy function for a 80 years old retired household. At this age, in the original means-tested economy, such household would only be subject to an assets means-testing stemmimg from the SSI. Besides the SS benefits and the households savings, the only other source of income available are the benefits of this program. In the left-hand side graph, one can see how the policy function of the agent becomes flat once it hits the assets-testing constraints.

The intuition behind that is that at certain level of assets, the household prefers to choose to stay exactly at the constraint in order to seize the benefit payed by the program. It has strong incentives to do so, as by choosing to save a smaller amount than it would otherwise for that level of asset, it can increase its current period consumption not only by dissaving, but also by having access to a larger income. On the right-hand graph, this trade-off is made clearer, as in the UBI economy, such distortion does not exist and hence the policy function for assets does not stay constant for such a wide range of the assets' state-space and allows the household to achieve higher values, an expected result of releasing a constraint in the dynamic programming problem. All lines lie below the 45 degree line, showing that this is a dissaving region, consistent with the retirement period of the household.

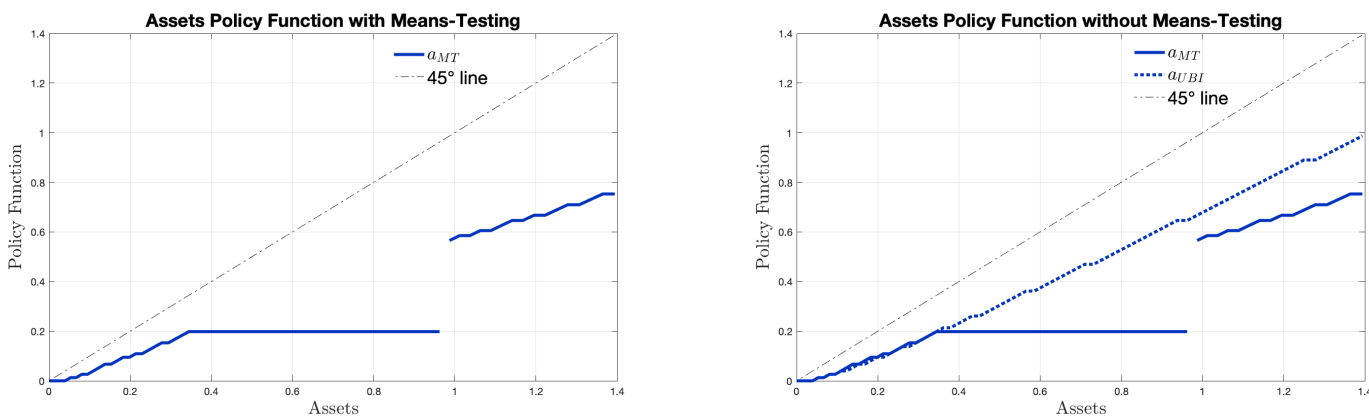

Figure 1: Distortions stemming from assets means-testing in the comparison between the benchmark economy as the first counterfactual UBI scenario.

Figure 2 portrays the labor supply distortions at low asset holdings and low and high productivity households in the means-tested economy. It zooms in the state-space of a household with 40 years old, and distinguishes on whether it has children or not. On the left-hand side, we can see from top to bottom the differences in labor supply allocations between productivity levels in both economies. When subject to means-testing, households with low productivity refrain from working in order to seize the transfers. As the assets-testing of the EITC is on investment income, hence non-binding for households at the bottom of the wealth distribution, the highest incentive to adjust is on the labor supply margin. Comparing the top and bottom graphs, it is clear the effect of the absence of testing, as households in the UBI economy only choose to drop their labor supply to zero at much higher levels of assets.

The opposite behavior happens with households with high productivity. Even though adjustments are small, one can observe that for high productivity agents, labor supply under the UBI economy is smaller for any asset level. This happens because their extensive margin adjustment is unaffected by the design of the transfer system. However, with the extra transfer received unconditionally under the UBI regime, households, who dislike working, can slightly decrease their intensive margin to sustain a similar level of consumption.

On the graphs on the right-hand side, we see the difference in behavioral responses for agents with children. For low productivity agents, the reaction to the change in regime of transfer is identical to the one mentioned previously: in the UBI economy, low productivity households are fre to work more obtain an increment income without loosing their transfers. However, for the high productivity households with children, the response now operates in the reverse direction than before. As the initial means-tested system for them was roughly being accessed via the EITC, the generosity of the money received is then heavily dependent on the presence of children in the household. Hence, households before had the incentive to work at their initial level and obtain sizeable amounts of transfers. In the UBI economy, as it is independent on the number of children for the money received by the household, labor supply has to be higher in high level of assets.

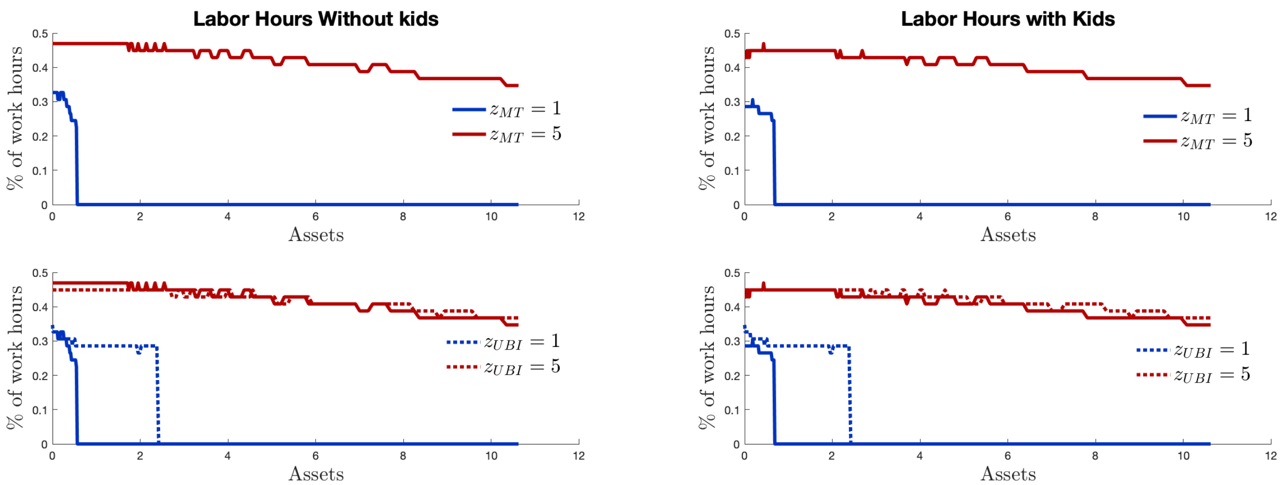

Figure 2: Distortions stemming from earnings and assets means-testing in the comparison between the benchmark economy as the first counterfactual UBI scenario.

6.2 Andrew Yang's UBI

The second counterfactual conducted is a non-neutral increase on the the total amount of transfers TR of the economy to the level equivalent to $TR/Y = 20\%$ in the initial steady-state. This exercise is inspired by the policy proposal advocated by Andrew Yang, a candidate to the primaries of the Democratic Party for the presidential election of the United States in 2020[11]. The thought experiment is then to give every agent in the economy a UBI that would amount to US$12,000 per year, or US$1,000 monthly. We proceed in an otherwise identical fashion as the previous counterfactual exercise.

Table 7 below shows the results for the aggregate quantities. As expected, the budget cost to raise the level of transfers to the desired level is high and hence the taxation on consumption has to climb up to 30.9% to balance the government's budget. Such high taxation combined with the high level of transfers end up driving agents to react sharply in terms of their labor supply. The intensive margin captured by the aggregate hours decreases substantially, reducing about 9 percentage points. The same sharp drop is seen in the LFP, which now shows that less than a half of the households work in this economy.

[11] Andrew Yang's "Freedom Dividend" policy proposal can be found on this link.

These large movements in the labor side of the economy are partially driven by the non-convex structure present in the labor supply. With the commuting costs, the aggregate response in labor is amplified due to the larger macro Frisch elasticity that this formulation yields. As the environment is in general equilirbium, there is an accompanying adjustment of the wage rate, which increases by more than 3%. As we have seen in the exercise for the Alaska experiments, this force attenuates the effects on the labor side of the economy, but in the case of this large level of transfers, the rise in the return to labor is not enough to prevent the large drop observed.

The overall result is that the economy contracts significantly and becomes much more unequal in terms of pre-tax labor earnings and wealth. However, both the capital-to-ouput and the consumption-to-output ratios increase due to the fact that the output decreases relatively more than K and C. Lastly, the total stock of human capital in the economy HC, exhibits a substntial decrease when compared to the former steady-states, but a higher value in terms of GDP whe compared with the former counterfactual . This result stems from a selection effect operating behind the extensive margin: low productivity agents sort themselves into zero labor supply due to the generous consumption floor created by the UBI while high productivity agents remain attached to the labor force throughout their life-cycle with virtually no depreciation of their individual human capital. The rearrangement towards inequality shown by the Gini is then a byproduct of such process and happens directly through the accrual of more earnings and wealth at the top that arise through the shap drop in labor of low productivity households. This result is further seen in Table 8.

Table 7: Comparison of aggregates.

Variable	Means-Tested	UBI	UBI AY
Y	100	105.2	86.9
K	100	110.7	91.7
L	100	102.3	83.4
C	100	103.2	88.7
HC	100	99.9%	82.9%
H	33.1%	33.1%	24.9%
LFP	69.1%	68.6%	47.0%
K/Y	290.0%	305.2%	308.3%
C/Y	64.3%	63.1%	66.1%
L/Y	56.3%	54.8%	54.5%
HC/Y	288.1%	273.6%	277.2%
TR/Y	3.8%	3.6%	23.0%
w	1.153	1.185	1.191
r	0.042	0.036	0.035
τ_c	8.1%	7.8%	30.9%
Earnings Gini	0.44	0.46	0.55
Wealth Gini	0.69	0.77	0.79

Note: The column with name "Means-Tested" shows the results of the benchmark model, the column with label "UBI" shows the results for the expenditure-neutral counterfactual and the column with name "UBI AY" shows the results for the exercise inspired by Andrew Yang's proposal.

6.3 Impact on Inequality

Table 8 shows the distributional outcomes of disposable income and consumption for the benchmark means-tested model and the two scenarios under the UBI counterfactual. We can observe that the expenditure-neutral UBI is slightly less redistributive after tax and transfers than the benchmark model. More specifically, the bottom quintile exhibits significant growth in accrued income under the UBI, which arises as a reshuffling from income from the second and third quintiles. The small UBI is not uniformly progressive as the highest quintile also obtain more post-tax income, mostly coming through their increase in savings. The second UBI counterfactual exhibits the same pattern but with slightly more distribution coming from the very top and a sifgnificant reshuffling from the second to the first quintile. It is noteworthy that, even though pre-tax inequality increases in both counterfactuals as shown in Table 7, post-tax inequality decreases with some progressivity.

Regarding consumption inequality, the first UBI economy is less equal with a redistribution from the bottom two quintiles to the the two immediate upward quintiles, while the second UBI economy exhibits similar inequality to the benchmark and less than the first counterfactual economy with a cascading effect coming from the top quintile towards the immediate two bottom quintiles.

Table 8: Comparison of quantiles between benchmark and counterfactuals.

	Disposable Income			**Consumption**		
	MT	UBI	UBI AY	MT	UBI	UBI AY
Quantile						
Bottom 20%	0.4%	1.3%	5.7%	9.6%	7.2%	8.4%
20% - 40%	7.1%	7.0%	6.0%	14.0%	11.6%	13.0%
40% - 60%	15.0%	12.2%	12.3%	16.1%	18.0%	19.0%
60% - 80%	29.2%	28.4%	28.0%	23.5%	27.0%	26.0%
80% - 100%	48.2%	51.0%	48.0%	36.7%	36.1%	33.5%
Gini	0.49	0.50	0.45	0.26	0.30	0.26

Note: The column with name "Means-Tested" shows the results of the benchmark model, the column with label "UBI" shows the results for the expenditure-neutral counterfactual and the column with name "UBI AY" shows the results for the exercise inspired by Andrew Yang's proposal.

6.4 The Government Budget Constraint

In light of all the movements shown previously, it is worth to take a deeper look at how the transmision of inequality affects the aggregate outcomes. More specifically, one highly affected equilibrium object is the government budget constraint. In Table 9, I show the breakdown of the budget by each of its sources and for each of the three steady-states analyzed so far.

As can be seen in Table 6, the tax rate on consumption, τ_c, decreases moderately in the first counterfactual. This result is intuitive as all the aggregate inputs which suffer the incidence of taxation increase in comparison with the benchmark economy. In the breakdown below, the revenue stemming from the progressive taxation on labor and from the taxation on assets is slightly smaller, in terms of GDP, than in the benchmark. This lack of adjustment accomodates the needs of resourcing from consumption, allowing for the drop in the rate.

For the second counterfactual, the increase in the consumption tax revenue can be understood together with the movements shown in Table 7. Naturally, as a higher level of TR/Y needs now to be financed, τ_c increases sharply. However, as low productivity households drop of out of the labor force, while the high productivity ones keep working, total labor input L/Y and aggregate human capital HC/Y per GDP, do not fall as much when compared to the first counterfactual. This allows for total revenue stemming from progressive taxation TL/Y to be higher in the breakdown of the budget than in previous steady-states which attenuates the increase in consumption revenue needed to fund the large UBI.

Table 9: Comparison of sources of revenue between benchmark and counterfactuals.

Variable	Means-Tested	UBI	UBI AY
Revenues			
$\tau_c C/Y$	5.2%	4.9%	20.4%
$\tau_r rA/Y$	1.1%	1.0%	1.0%
TL/Y	1.9%	1.8%	5.6%
Q/Y	4.8%	4.7%	4.7%
Revenue$/Y$	13.0%	12.4%	31.7%
Expenditures			
TR/Y	3.8%	3.6%	23.0%
G/Y	7.2%	7.2%	7.2%
$(r - g_n)B/Y$	2.0%	1.6%	1.5%
Expenditure$/Y$	13.0%	12.4%	31.7%

Note: The column with name "Means-Tested" shows the results of the benchmark model, the column with label "UBI" shows the results for the expenditure-neutral counterfactual and the column with name "UBI AY" shows the results for the exercise inspired by Andrew Yang's proposal.

7 Transitional Dynamics

The exercise conducted in the transitional dynamics consists of starting at the initial steady-state at period $t = 0$ and, at period $t = 1$, enact the counterfactual reform. The policy is permanent and unexpected by the agents. The generations $j = 1, \ldots, J$ that were alive in period $t = 0$ will reoptimize to adapt themselves to the new scenario and prices at the capital and labor markets adjust along the transtion path clearing all markets in the economy. The adjustment to the new steady-state is close to achieved in 37 periods, which I use as the maximum due to computational purposes.

7.1 Aggregates

Figure 3 below depicts the transitional dynamics of the main aggregate variables and of prices after an the enaction of each of the UBI counterfactual reforms. The left-hand side shows the expenditure-neutral UBI, while the right-hand side shows the generous UBI.

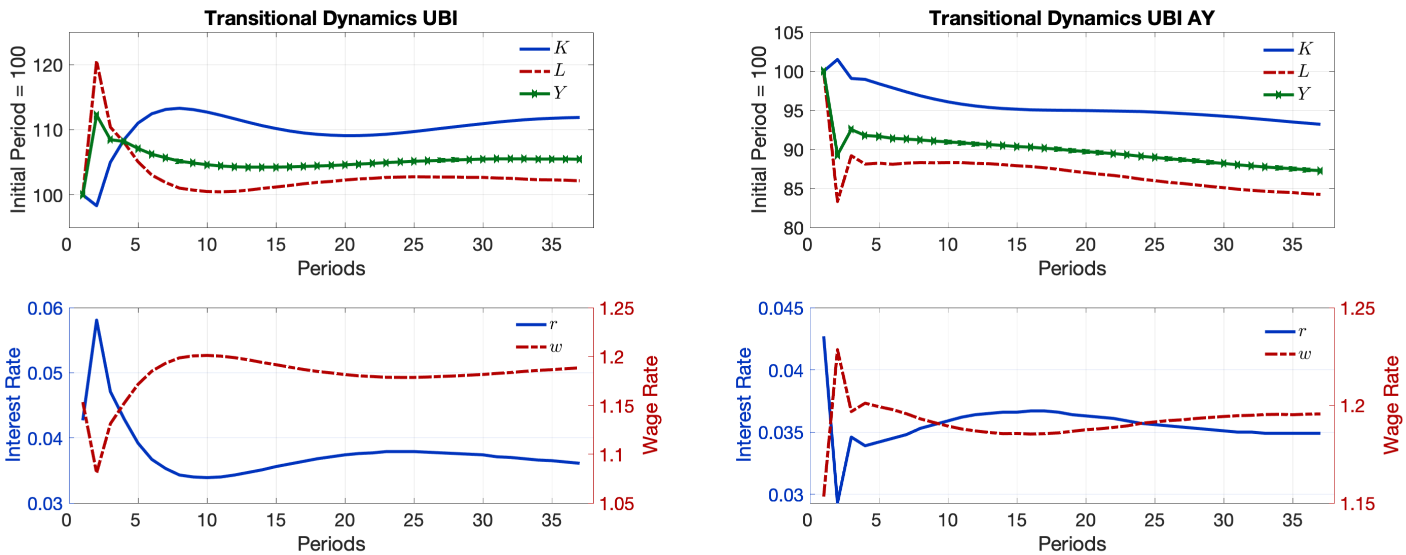

Figure 3: Transitional dynamics of aggregate variables for the two counterfactual exercises.

When the first reform is enacted, agents immediately and largely adjust their labor supply decisions due to the loss of the generous means-tested transfers to a low level of UBI. This reaction can be observed by the spike in the aggregate labor L which achieves a level 20% higher than the one of the initial steady-state. Moreover, there is also the trade-off between consumption and savings which can be seen in the decrease of aggregate capital K. The drop in capital at the initial period is nonetheless much smaller relative to the jump in labor, only starting to increase to the higher levels of the new steady-state 3 years after the reform. At the final periods, one can observe that the equilibrium trades the initial movement of the labor supply for the increase in savings, then achieving the aggregates in the new steady-state, all higher than their initial levels. The adjustment in prices simply follows the behavior expected from the decreasing marginal returns of the neoclassical production function.

There is a symmetric initial response of the aggregate variables and prices between counterfactuals. The second reform, the one of Andrew Yang's level of UBI, yields precisely the opposite signs of change in the aggregates. With the new and and unexpected large transfer, agents drop out of the labor force and work significantly less, thus reducing L by more than 15%, which then later settles to its lower level. The extra income combined with the exclusion of assets-testing causes a small increase in the level of K, which later converges to the smaller level in the new-steady-state due to the decrease of precautionary savings and hours worked allowed by the UBI's consumption floor. An important fact observed in the transition of this counterfactual is the adjustment in K being relatively slower and smoother than in the first reform.

7.2 Inequality at the Transition

In Table 10, I show the distributions of disposable income and consumption at the first period of the transition. The inequality when the reform is enacted highlights the differences between short and long run that drive the welfare results explained in the next section. When compared to Table 8, one can immediately notice that for the second counterfactual, the generous UBI, there are mostly small differences in the results of all of distributions shown.

For the first exercise, however, there are amplifications in the increase of inequality in consumption. Differently than in the long run, there is less consumption being accrued at the bottom and significantly more at the top. The intuition behind this lies on the fact that for the low strand of the distribution, the amount of transfers received is smaller than before while for the top earners, their return to work is high enough for their labor behavior to be positively affected, allowing for more consumption together with the UBI top-off. The Gini index of the consumption distribution is in this case 11 points higher than the benchmark and 7 points higher than its equivalent in the steady-state, reflecting the shift of accrual towards the top.

Table 10: Comparison of quantiles between benchmark and counterfactuals.

	Disposable Income			Consumption		
	MT	UBI	UBI AY	MT	UBI	UBI AY
Quantile						
Bottom 20%	0.4%	2.0%	5.7%	9.6%	5.9%	8.5%
20% - 40%	7.1%	7.7%	5.9%	14.0%	10.3%	13.0%
40% - 60%	15.0%	13.3%	12.9%	16.1%	17.2%	20.0%
60% - 80%	29.2%	26.9%	28.3%	23.5%	23.9%	25.5%
80% - 100%	48.2%	50.0%	47.1%	36.7%	42.6%	32.9%
Gini	0.49	0.48	0.44	0.26	0.37	0.25

Note: The column with name "Means-Tested" shows the results of the benchmark model, the column with label "UBI" shows the results for the expenditure-neutral counterfactual and the column with name "UBI AY" shows the results for the exercise inspired by Andrew Yang's proposal.

8 Welfare

In this section I conduct an evaluation of both reforms through an analysis of the welfare responses in the short and long run. The context for the welfare analysis is an inquiry on whether or not to means-test the income security net of the government based on the computation of a chosen measure of social welfare. Given the initial conditions, I follow Conesa et al. (2008) and define the utilitarian Social Welfare Function (SWF) for a newborn agent as follows:

$$W(\{\tau\},\zeta,TR) = \int_S v^*(a=0,h=1,z=\bar{z},k,\theta,j=1\,|\,\{\tau\},\zeta,TR)\,d\Phi^* \qquad (19)$$

where $\{\tau\}$ are all the taxation parameters, ζ is the collection of means-testing parameters, $\zeta = \{\bar{y}^k_{TC}, \bar{d}_{TC}, \ldots\}$, TR is the aggregate level of total transfers, and $\{v^*, \Phi^*\}$ are the equilibrium value functions and distributions.

In Table 11 below, I show results for welfare evaluation through the comparison of the three steady-states studied so far as well as the transition between the benchmark and each of the counterfactuals. I report the aggregate steady-state welfare for households with age $j = 1$, i.e., the discounted expected value of being born in each economy through the *Consumption Equivalent Variation* (CEV). This measure defines the increment in consumption that we would need to give households in each state of the world so that they would be indifferent between their level of consumption in the alternative economies, hence *under the veil of ignorance*:

Table 11: Comparison of Consumption Equivalent Variation.

	UBI	**UBI AY**
CEV Steady-state	-0.14%	0.08%
CEV Transition	-0.20%	0.12%
Votes	62.30%	83.87%

Note: The column with label "UBI" shows the results for the expenditure-neutral counterfactual and the column with name "UBI AY" shows the results for the exercise inspired by Andrew Yang's proposal.

The CEV required is of -0.14%, making the expenditure-neutral UBI a policy that reduces welfare under an utilitarian SWF. The opposite is true for the US$1,000 UBI, with an increase of 0.08% in welfare. If we take into account the welfare cost at the transition, - i.e. the cost to the generations that were alive in the period the reform is enacted and whose choice need to be reoptimized - we observe that the effects of both reforms is amplified. The intuition behind the amplification lies on the distributional consequences seen before. We have seen in Table 10 that inequality in consumption is higher than in the steady-state, with the disutility of work affecting more the top, and the dampening of consumption the bottom. Lastly, at the period when the reform is enacted, if we could subject the proposal to a voting by the generations alive in that year it would be implemented, it would receive a sound majority in the second scenario, but also a majority in the first, despite the decrease in welfare. The following section unpacks the forces behind such votes.

8.1 Decomposing the Welfare Effects

In order to understand better who are the winners and losers of both reforms, it is useful to decompose the welfare changes in different cuts of the state-space. To get a better sense of the role of the age dimension, I plot below the cross-sectional average of the value function over the life-cycle, which can be equivalently defined as an age-dependent SWF in terms of CEV. I do so by showing the average between decades of households' lives. Figure 4, shows the comparison between the two counterfactuals both at their steady-states and at the enacted period of the reform.

We can observe in the plot on the left-hand side that the expenditure neutral system exhibits negative levels of welfare than the benchmark scenario mostly in the beginning of the life-cycle. As households have children in early ages and the targeted transfers generosity is biased towards families with children, it is natural that a transfer with an average level lower than before leaves agents worse-off in that period of their lives. However, as soon as households start seizing the increasing path of their earnings profile, the savings they accumulate under the new UBI regime shifts the dominance of welfare. In effect, households in the benchmark economy at those periods are trapped working less effective hours and saving less to remain inside the constraints that guarantees the reception of the benefits. Eventually, in later ages, after the dissaving process is exhausted in each economy, welfare of both converges to similar levels. During the transition, the losses are larger and for a larger number of years in households' lives. The age dimension also helps us to unveil the source behind the votes shown in Table 11, as ther percentage in favor of the reform tracks closely the relative share of ages that have welfare below the benchmark scenario.

Regarding the second counterfactual, in the long run, the welfare is slightly positive for the very first ages, being then negative for a long part of the working years almost all the way through retirement. Without the breakdown through the life-cycle, this effect is masked by the comparison only of newborn households. An important part of the positive welfare changes only happen at retirement, mostly due to the abence of the assets means-testing of the SSI, a fact common in all profiles in all comparisons. At the enacted period of the transition, on the other hand, the gains are uniformly positive across all ages of the cross-section. This once again emphasizes the benefits of simultaneously working less while seizing a high consumption floor in an economy that starts with a large amount of capital that slowly decreases. The voting pattern of more than 80% in favor is thus a natural consequence of this picture.

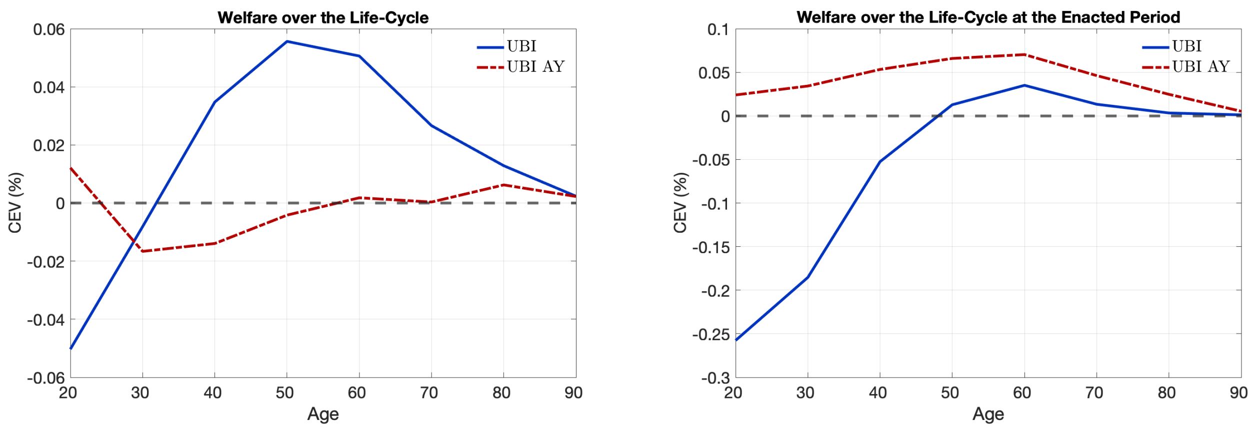

Figure 4: Value functions over the life-cycle between steady-states and at the period when the reforms are enacted.

Another important dimension of decomposition is the permanent ability level of the households. The value θ is the only source of labor income heterogeneity of households' initial conditions and directly tracks the overall level of earnings inequality captured by the Gini index. In Table 12, one can observe the breakdown for the two points in which I discretize this shock. Given the way that wage risk was estimated, this points can be roughly interpreted as a comparison of college and non-college levels of initial ability. The results for the steady-states show that there is an inverse pattern between the two counterfactuals. In the small UBI economy, low ability households are worse-off due to the expected lack of generosity of the income security system in the first ages of their lives. High ability households, on the other hand, will mostly probably be attached to the labor force with high efficiency units and thus have small but positive welfare stemming from the unconditional transfers. In the second counterfactual, the direction is opposite, as high ability agents will mostly likely be the ones suffering the hike in taxation needed to sustain the reform, they benefit little from the new policy. Low ability households, on the other hand, anticipate the abundance of leisure and consumption in relative terms and accrue a substantial part of the gains.

Table 12: Decomposition of Consumption Equivalent Variation.

CEV	**UBI**	**UBI AY**
Steady-State	-0.1393%	0.0798%
Initial Heterogeneity		
Low ability	-0.1779%	0.0782%
High ability	0.0386%	0.0016%

Note: The column with label "UBI" shows the results for the expenditure-neutral counterfactual and the column with name "UBI AY" shows the results for the exercise inspired by Andrew Yang's proposal.

9 Conclusion

In this paper, I addressed the question on what would be the impact of a nationwide reform of the U.S. welfare system to a Universal Basic Income proposal. I have developed an overlapping generations model with idiosyncratic income risk that incorporates both intensive and extensive margins of labor supply, human capital accumulation through labor market experience, and child-bearing costs. The model has a welfare system with an income security net that matches the U.S. design and accounts for means-testing requirements in income and wealth and its taxation counterparts. The focus of my analysis lied in the changes in aggregates. inequality, government budget, and welfare.

I calibrated the model to the U.S. and conducted two counterfactual exercises implementing UBI reforms. In the first reform, an expenditure-neutral level of unconditional transfers generates an income effect that lead households in the UBI economy to work more hours and decrease the participation in the labor force. Due to the absence of restrictions on maximum level of assets, households save more and aggregate capital increases, followed by an increase in output of 5.2%. I have not found a large impact on revenue requirement, as the endogenous tax rate on consumption decreases by a percentage point to sustain such reform.

In my second counterfactual exercise, I implement Andrew Yang's proposal of UBI. I let the level of transfers be of US$12,000 annualy to each agent in the economy. In this scenario the tax rate on consumption needs to increase 22 percentage points in order to balance the government's budget. The aggregate response of the economy is a contraction of both capital and output. Both UBI reforms increase the Gini coefficient for pre-tax earnings and wealth, mostly due to the selection mechanism arising from the high productivity agents that remain in the labor force and are able to buffer consumption through higher level of savings. However, there is more equality in disposable income with a large redistribution towards the bottom 20%, driven by a reduction of the means accrued by the middle-class.

The welfare system under the expenditure-neutral UBI yields a welfare loss of -0.14% in Consumption Equivalent Variation relative to the initial means-tested welfare system. The UBI economy achieves a lower welfare than the current IS system in early ages when households have children but then exhibits a higher welfare in later ages and a lower variance of consumption during the retirement years. Alternatively, the generous UBI transfer improves welfare in 0.12%, exhibiting gains for almost all ages alive during the transition.

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Appendix

A Data - SIPP 2008

In this section I outline the empirical evidence obtained from the the 2008 panel of the *Survey of Income and Program Participation* (SIPP). The SIPP is a representative sample of the civilian United States population and provides information on earnings, transfers from different U.S. income security programs, a fine breakdown of households' balance sheet and detailed demographics which are used in the calibration of the model for the U.S. economy. The SIPP is the natural candidate of household survey data for this paper's question as it has detailed questions for many of the programs designed to target this stratum of the population.

The 2008 panel consists of 16 waves for which interviews are conducted every 4 months. The sample selection used spans through May 2008 to December 2013, and is observed monthly. I deflate all values with the CPI for the last month in my sample and restrict the observations units to be at the household level in which the head of the household age is between 20 and 65. In the SIPP, I use the classification *reference person* to follows observation units. I guide the empirical documentation following a methodology similar to the one used in Kaplan et al. (2014) and Kuhn and Rios-Rull (2015), in which authors characterize several measures of inequality in different household survey datasets. In particular, I construct equivalent definitions of Net Iliquid and Net Liquid Wealth from Kaplan et al. (2014) for the SIPP questionnaire. The data for assets is taken from the Topical Modules of the 2008 Panel. I cross-check with their estimates and find similar qualitative patterns and orders of magnitude.

A.1 Summary Statistics

The Table 13 below displays the summary statistics for my sample:

Table 13: Sumarry statistics. Source: SIPP 2008

Variable	Mean	Std. Dev.	Min	Max
Earnings	5,952.1	5,855.7	1.0	137,984.6
Income	6,698.3	5,964.5	-5,163.9	139,644.9
Cash Transfers	36.4	206.5	0.00	5,239.1
Net worth	242,136.7	806,620.6	-729,020.1	1,903,800
Net liquid wealth	193,187.4	269,582.1	-453,567.4	2,427,526
Checking accounts	133.0	688.5	0.00	8,099.4
Bonds	260.6	2,067.8	0.00	32,397.8
Credit cards	907.7	2,650.8	0.00	16,198.9
Loans	747.5	7,041.0	0.00	125,000.0
Debt	759.6	4,324.7	0.00	48,596.74

Tables 14 and 15 below characterize the percentiles partition for the distribution of several statistics.

Table 14: Distribution for the SIPP 2008 panel.

Percentiles	1	5	10	25	50
Earnings	195.3	695.6	1,177.6	2,334.6	4,439.4
Income	517.9	1,287.7	1,796.8	3,054.9	5,192.1
Net worth	-70,007.4	-2,809.9	159.7	10,579.1	90,092.4
Net liquid wealth	-45,000.0	-12,912.3	-5,399.6	-186.3	0.0
Net illiquid wealth	-75,054.9	0.0	0.00	0.00	91,557.3

Table 15: Distribution for the SIPP 2008 panel (continued).

Percentiles	75	90	95	99	Gini
Earnings	7,736.7	11,927.6	15,428.5	32,886.0	0.44
Income	8,510.2	11,2731.5	16,300.4	33,486.1	0.43
Net worth	302,189.8	651,205.9	964,770.5	185,131,1	0.70
Net liquid wealth	0.0	77.4	917.9	7,984.6	–
Net illiquid wealth	276,461.4	548,279.5	761,348.9	1,208,344	0.70

Table 16 below displays the correlations between the statistics calculated.

Table 16: Joint distribution for the SIPP 2008 panel.

	Earnings	Income	Net worth	Liq. wealth	Illiq. wealth	Transfers
Earings	1.00					
Income	0.9874	1.00				
Worth	0.4027	0.4344	1.00			
Liq. wealth	-0.0889	-0.0849	-0.0086	1.00		
Illiq. wealth	0.4057	0.4373	0.9994	-0.0263	1.00	
Transfers	-0.0837	-0.0390	-0.0575	0.0139	-0.0580	1.00

B Estimation of the Wage Process

I annualize the monthly data on labor earnings from the SIPP 2008 in order to estimate the idiosyncratic income risk present in the model. I run the regression on log wages in equation (20) below and obtain the income residuals used in the GMM estimation.

$$\log W_{ijt} = c + \mathbf{D}_t + \mathbf{E}_{ijt} + \nu' \mathbf{A}_{ijt} + w_{ijt} \tag{20}$$

where i stands for household, W_{ijt} are wages obtained dividing earnings by hours worked, c is a regression constant, $\mathbf{D}_t$ are time dummies for the years of observation 2008-2013, $\mathbf{E}_{ijt}$

are dummies that control for two levels of schooling - less or equal than high school college degree and some college or above degree -, and $\mathbf{A}_{ijt}$ stands for a cubic polynomial on years of potential labor market experience, which are tied to age. Table 17 shows the result for the Mincerian regression.

Table 17: Regression results for equation (20).

Dependent Variables	$\log W_{ijt}$
D_{2009}	-0.0159***
	(0.00177)
D_{2010}	-0.0318***
	(0.00192)
D_{2011}	-0.0523***
	(0.00208)
D_{2012}	-0.0473***
	(0.00226)
D_{2013}	-0.0416***
	(0.00260)
E_2	0.221***
	(0.00519)
ν_1	0.0535***
	(0.00151)
ν_2	-0.00138***
	(7.02e-05)
ν_3	9.54e-06***
	(9.88e-07)
Constant	1.273***
	(0.0112)
Observations	1,161,201
Number of Households	34,653

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Following Heathcote et al. (2010), I assume stationarity and postulate that the log residuals follow a process with persistent and transitory shocks, z and η, respectively:

$$w_{i,j} = \eta_{i,j} + z_{i,j},\ \ \eta_{i,j} \sim N(0, \sigma_\eta^2),\ \ z_{i0} \sim N(0, \sigma_{z_0}^2) \tag{21}$$

$$z_{i,j+1} = \rho z_{i,j} + \varepsilon_{i,j},\ \ \varepsilon_{i,j} \sim N(0, \sigma_\varepsilon^2) \tag{22}$$

The parameters from this process can be identified in levels by the theoretical moments. More precisely, ρ is identified by the slope of the autocovariance of z at lags greater than 0; σ_ε^2 and σ_η^2 are both identified by the difference between variance and autocovariance of u, and $\sigma_{z_0}^2$ can be obtained residually from $var(z_{i,0})$.

I drop households with non-positive earnings ending with a sample of 1.2 mm observations with which I conduct an over-identified GMM estimation using the identity matrix, as the weighting matrix Ω[12]. Table 18 below shows the obtained estimates.

Table 18: Estimation of the income process.

Ω	$\hat{\rho}$	$\hat{\sigma}_\varepsilon^2$	$\hat{\sigma}_\eta^2$	$\hat{\sigma}_{z_0}^2$
Identity	0.9342	0.0176	0.3595	0.3975

C Calibration of Means-Tested Programs

The model uses three different types of means-tested transfers with parameters that require mapping to the data: the EITC, the SNAP/TANF, and the SSI. I will explain in detail how I proceed for each parameter of each program.

The requirements for the EITC are defined by the IRS. First, there are the *Earned Income* limits that allow households to be eligible for the program. In the model they are defined

[12]The suggestion can be found in Guvenen (2009), that uses this matrix as it a standard in the literature for small sample estimations.

by the variable $\bar{y}^{k}_{TC}$, which depends on the number of children present in the household $n_{k,j}$. I define these quantities in terms of model units as shares of GDP per households. As households have unit mass, this simply means shares of the final good Y. For example, the total *Earned Income* limit in 2019 for a taxpayer filing as a head of household with one child is US$41,094. Assuming a GDP per capita in the U.S. of $60,000, this yields 25.95% of GDP. In the model then, I define $\bar{y}^{n_{k,j}=2}_{TC} = 0.26 * Y$. As in the simulated economy there is no notion of marriage and the data used in the SIPP is based on a sample in which the observation unit is characterized by the *reference person*, I use the data for taxpayers filing as head of household in the case of the EITC. An analogous procedure is then used for the subsequent thresholds depending on the number of children.

The limit on *investment income*, $\bar{d}_{TC}$, is, as of 2019, is US$3,600 and independent on the number of children in the household. For this parameter, my preferred choice of mapping is in relation to average assets per capita, A. As I will use a similar calculation for the assets-testing of the other programs, I will map them to the mean *Equity in 401k and Thrift savings accounts* calculated for my sample of the SIPP data. The limit is then exactly 9.81% of this value. As A is an endogenous variable in the model and it is more tractable to define the threshold on assets exogenously, I solve the model several times and set a value that with some certainty lies close to the one calculated for the threshold in the data. At the final steady-state for the benchmark economy, the restriciton on assets for the EITC is approximately 9% of average assets. Table 19 below collects all the aforementioned parameters.

Table 19: EITC parameters.

# Children	$\bar{d}_{TC}$	Target	$\bar{y}_{TC}$	Target
$n_{k,j} = 0$	0.23	$\approx$ 9% of A	0.19	$\approx$ 26% of Y
$n_{k,j} = 1$	0.23		0.51	$\approx$ 69% of Y
$n_{k,j} = 2$	0.23		0.64	$\approx$ 87% of Y
$n_{k,j} = 3$	0.23		0.69	$\approx$ 93% of Y

The phase-in and phase-out rates κ_1 and κ_2 are independent of units and are thus taken exactly as the ones defined by the IRS for 2019. The phase-in level $\underline{y}$ multiplied by the phase-in rate yields the maximum credit amount at each child level. For example, for a taxpayer filing as a household with no children, the maximum credit is US$529 per year and $\underline{y}^{n_{k,j}=0}$ is US$6,920, which is approximate 11% of GDP per capita. Both the phase-in and phase-out levels are similarly defined in terms of percentages of Y[13]. Table 20 collects all remaining details of the parametrization of the EITC.

Table 20: EITC parameters.

# Children	κ_1	κ_2	Target	$\underline{y}$	Target	$\bar{y}$	Target
$n_{k,j} = 0$	0.0765	0.0765	IRS	0.08	$\approx$ 11% of Y	0.10	$\approx$ 14% of Y
$n_{k,j} = 1$	0.3400	0.1590		0.12	$\approx$ 16% of Y	0.22	$\approx$ 30% of Y
$n_{k,j} = 2$	0.4000	0.2100		0.18	$\approx$ 24% of Y	0.23	$\approx$ 32% of Y
$n_{k,j} = 3$	0.4510	0.2100		0.18	$\approx$ 24% of Y	0.23	$\approx$ 32% of Y

The cash transfers parameters are defined in a similar fashion. First, it is important to notice that recently there has been a change in the requirements of assets limits for SNAP and TANF. By 2018, 37 states abolished the test for food stamps and eight for the TANF (Wellschmied, 2018). As I am bundling both programs together, I keep the assets means-testing with the constraint $\bar{d}_{CT}$. In the tax code this test is made on households' *resources* which vary by program. I will keep the mapping with the 401k accounts used before for the EITC. Currently, for SNAP, the *U.S. Department of Agriculture* (USDA) defines a maximum of US $2,250 in countable resources or US$3,500 if at least one member of the household is of age 60 or older. A recent study by the *PEW Charitable Trusts* identifies that more than half of the States in the U.S. use a threshold between US$1,000 and US$2,500. I choose US$2,500 which is 7% of the average equity in the SIPP sample and proceed in the same way of the EITC to map it to about 7% of A in the benchmark economy[14].

[13]All details regarding the numbers and limits here used can be found at this IRS link and at this link from the *Center on Budget and Policy Priorities*.

[14]The website of the USDA that defines all criteria for SNAP from 2019 to 2020 can be found in the

For the income limit $\bar{y}_{CT}$, I use the value defined by the USDA for maximum gross income for a household of size 2. This maps in the model to about 40% of Y. I proceed in the same way for the annual benefit t_{SNAP}. The USDA defines a monthly benefit of US$355, which compounds annualy to approximately 7% of the GDP per capita. Table 21 below summarizes the information for the SNAP/TANF transfers.

Table 21: Cash transfers

Test	$\bar{d}_{CT}$	Target	$\bar{y}_{CT}$	Target	t_{SNAP}	Target
Value	0.20	$\approx$ 7% of A	0.30	$\approx$ 40% of Y	0.07	$\approx$ 10% of Y

Finally, the only remaining program is the SSI, which in the model environment is only attainable during retirement. The SSI is tested only on *resources*, which in this case do not count households' house or vehicles. The maximum defined by the *Social Security* is US$2,000 for an individual and US$3,000 for a couple. I map that as approximately 6% of A. The monthly benefit rate defined by the SS is US$771 for an individual and US$1,157 for a couple. However, the SSI benefit suffers deductions if the household receives SS pensions. In the model all retired households receive a benefit $b(x_t)$ equal to 36% of the average income of the simulated economy, which amounts to the equivalent of US$2,160 monthly. If I were to follow directly the deduction schedule, households would not receive any SSI benefits. As a compromise, I set t_{SSI} as 1% of Y, yielding a monthly transfer of US$65[15]. Table 22 below shows all values used for the SSI.

following link. The website with the PEW study about limits on family assets in the context of the TANF can be found in this link.

[15] The website of the SS for the *resources* criteria for the SSI can be found via this link. For the rules regarding the benefit rates one can go to this link .

Table 22: SSI parameters.

Test	$\bar{d}_{SSI}$	Target	t_{SSI}	Target
Value	0.18	$\approx 6\%$ of A	0.01	$\approx 1.3\%$ of Y

D Recursive Competitive Equilibrium

Definition 2 (Stationary Recursive Competitive Equilibrium). *A stationary recursive competitive equilibrium with population growth for this economy is an allocation of value functions $\{v(s), v^R(s)\}$, policy functions, prices $\{w, r\}$, an age-dependent but time-invariant measure of agents Φ, transfers and taxes such that:*

1. *The value functions $\{v(s), v^R(s)\}$ and policy functions $\{a'(s), c(s), l(s)\}$ solve the households' optimization problems (14) and (15), given the factor prices and initial conditions;*

2. *The individual and aggregate behaviours are consistent:*

$$G = g_y Y, \;\; B = g_b Y$$

$$(1 + g_n)K = \int_S a'(s) d\Phi - (1 + g_n)B$$

$$C = \int_S c(s) d\Phi$$

$$L = \int_S y(l(s), h, z) d\Phi \left(s_{-j}, \{1, \ldots, J_R - 1\}\right)$$

3. *$\{r, w\}$ are such that they satisfy the firm's first-order conditions (5) and (6);*

4. *The final good market clears:*

$$C + (g_n + \delta_k)K + G + CC = AK^{\alpha} L^{1-\alpha}$$

5. *The Government balances its budget:*

$$G + \int_S [T_{TC}(s) + T_{CT}(s)]\, d\Phi + (r - g_n)B =$$
$$\int_S \left[\tau_r r a(s) + \tau_c c(s) + \left(y(s) - \tau_0 y(s)^{(1-\tau_1)}\right)\right] d\Phi + Q$$

6. *Social Security's budget balances:*

$$\tau_{SS} w L = b(x) \int_S d\Phi \left(s_{-j}, \{J_R, \dots, J\}\right)$$

7. *Accidental bequests equals the savings left from dead households:*

$$Q = \int_S (1 - \psi_{j+1}) a'(s)\, d\Phi(s)$$

8. *Given the decision rules, Φ satisfies:*

$$\Phi(\omega) = \int_S M(s, \omega) d\Phi, \; \forall \omega \subset \mathcal{B}(S)$$

E Computation of the Model

E.1 Recursive Competitive Equilibrium

I solve for the households' problem by backward induction. The algorithm is similar to the one in Kindermann and Krueger (2018). Households surviving to the last period J have an immediate solution as $v_t^R(s_{-j}, J+1) = 0$. Aggregate quantities and prices are found by taking the following steps:

1. Guess initial values for K_t, L_t, $\tau_{c,t}$, and $\tau_{SS,t}$;

2. Given such initial values, use the firm's first-order conditions to obtain r_t and w_t;

3. Given prices and policy parameters, set value function after the last age to 0 and solve the value function for the last period of life for each point of the grid. This yields policy functions and value functions over retirement $v_t^R(s)$;

4. Also given prices and policy parameters, solve for the household's decision rules by backward induction and value function iteration repeating it until the first period of life;

5. Use forward induction to compute the associated distribution of households using the policy functions starting from the known distribution at the beginning of the life cycle;

6. Use the equilibrium conditions to update the values of the guessed variables and to compute all other aggregate variables;

7. Use dampening to obtain the new values for K_t and L_t, check the whether the associated markets clear;

8. Iterate until convergence.

E.2 Details of the computation

I discretize all continuous dimensions of the state-space: assets, human capital, productivity shocks, and permanent ability levels. I do so in 300, 50, 5 and 2 points, respectively. The children component is a binary index $k \in \{0, 1\}$, and the age list $j \in \{1, \ldots J\}$ has 80 points. The transition is assumed to converge in 37 periods, adding the associated number of points. I also discretize the labor choice in 50 points and use brute force grid search in the intra period decision of the household's labor supply. I include an extra loop for precision on evaluation of the extensive margin. The value function iteration to find the choice of next period's optimal assets is also done by brute force grid search. I use a grid with more nodes at the lower end. I also explore monotonicity and the envelope condition to increase efficiency. As there are values for the human capital allocation that lie outside of the state-space defined by the grids, I use linear interpolation in order to find indices for the next period's value function and the stationary distribution. Following Kindermann and Krueger (2018), I discipline the choice of the assets' grid $\{\hat{a}^1, \ldots, \hat{a}^i, \ldots \hat{a}^{300}\}$ by using the formula:

$$\hat{a} = \bar{a}\frac{(1+g_a)^{i-1}-1}{(1+g_a)^{299}-1} \tag{23}$$

where $\bar{a}$ is the upper bound of the discrete space which is chosen such that no household saves more than this amount and $g_a > 0$ is the growth of the distance between points.

F Life-Cycle Profiles

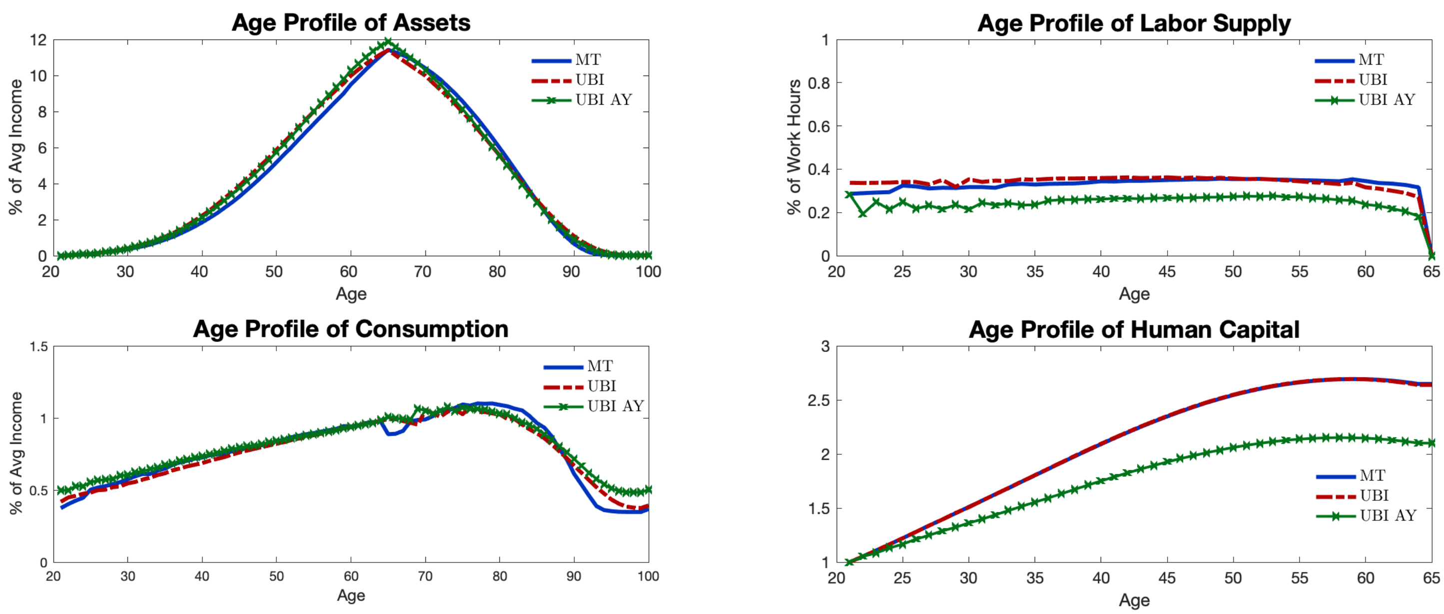

Figure 5: Average life-cycle profiles in the three steady-states analyzed.