Negative Income Tax and Universal Basic Income in the Eyes of Aiyagari*

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Abstract

We compare two redistribution programs—negative income tax (NIT) and universal basic income (UBI)—through the lens of Aiyagari (1994), a standard heterogeneous agent general equilibrium model. Mankiw (2020) proposes an example where an NIT and a UBI appear identical. We show that while Mankiw's example provides identical economic incentives to individual workers, the size of the government vastly differs. According to our quantitative analysis designed to replicate Mankiw's example, the UBI requires a program budget that is 15% of GDP, whereas the NIT requires 3.8% of GDP. Nevertheless, neither redistribution program significantly improves social welfare in the long run because of the reduction in capital and labor—via (i) tax distortion and (ii) a weak motive for precautionary saving and working.

Keywords: Redistribution, Negative Income Tax, Universal Basic Income, Government Budget

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1. Introduction

We compare two welfare programs—negative income tax (NIT) and universal basic income (UBI)—in a standard heterogeneous agent general equilibrium model. Mankiw (2020) proposes an example where the two programs appear identical. Consider two redistribution plans:

A. A means-tested transfer of $1,000 per month aimed at the truly needy. The full amount goes to those with zero income. The transfer is phased out: Recipients lose 20 cents of the transfer payment for every dollar of income they earn. These transfers are financed by a progressive income tax: The government taxes 20% of all income above $60,000 per year, which is close to the median household income in the U.S.[1]
B. A universal transfer of $1,000 per month for every person, financed by a 20% flat tax on all income.

According to Mankiw (2020), "*The two policies are equivalent because the net payment–that is, taxes less transfers–is identical under the two policies. A person with zero income gets $12,000 per year in both cases. A person with annual income of $60,000 gets zero in both cases. And everyone always faces an effective marginal tax rate of 20 percent. In other words, everyone's welfare is identical under the two policies, and everyone faces the same incentive. The difference between plan A and plan B is only a matter of framing.*"

We would like to make two comments here. First, the balanced budget is not guaranteed in either plan, unless the pivotal income ($60,000 in the above example) is exactly the average income of the economy in equilibrium. Second, while the net payments are identical, the total expenditure of the program will not be the same. The UBI is likely to require much larger spending because it has to provide the transfers to everyone *and* collect taxes from all. While the above example—and our model economy below—abstracts from any administrative cost of collecting taxes and providing transfers, there might be

[1] As of 2018, the median household income in the U.S. is $61,937, and the average household income is $87,864.

a non-negligible cost in implementing each plan.

To evaluate the outcomes of both programs quantitatively, we compare them in a standard heterogeneous agent general equilibrium model (*a la* Aiyagari (1994)) calibrated to match the salient features of the U.S. economy such as income and wealth distributions. According to our quantitative analysis, the UBI program that mimics Mankiw's example (but guarantees the balanced budget) requires tax revenue that is about 15% of GDP, whereas the NIT (which provides identical economic incentives) requires 3.8% of GDP. Nevertheless, neither redistribution program improves social welfare significantly in the long run as the reduction in capital and labor (due to tax distortion and a weakened motive for precautionary saving and working) roughly offsets the insurance benefit. The average welfare slightly decreases by 0.27% in terms of consumption equivalence units. Aggregate output, capital, and hours worked decrease by 12%, 22%, and 10% in the long run because of reduced savings and labor supply.

Finally, we consider an NIT program–which is a a slight modification of Mankiw's example—that improves social welfare in the long run. This program has the following features: (i) the pivotal income is the median (instead of the average income): i.e., the government transfer is restricted to more needy households (thus, as a result, the program requires a smaller program budget) and (ii) the income tax schedule is piece-wise linear (instead of simple linear) where the tax rate (7.4%) is chosen to balance the program budget in equilibrium. Under this policy, social welfare improves slightly (by 0.31%) and the tax-to-GDP ratio is 2%.

The remainder of the paper is organized as follows. Section 2 lays out the benchmark model economy, Aiyagari (1994), with an endogenous labor supply. We then introduce the two tax-transfer systems (NIT and UBI) and compare their outcomes quantitatively. Section 3 summarizes the results.

2. Quantitative Analysis

2.1. Model Economy

The model economy (which will serve as a laboratory for various quantitative analyses) extends Aiyagari's (1994) model to the endogenous labor supply.

Households: There is a continuum (measure one) of worker-households that have identical preferences and face an idiosyncratic productivity shock x, which evolves over time according to a Markov process with a transition probability distribution function $\pi_x(x'|x) = \Pr(x_{t+1} \leq x'|x_t = x)$. When a household with labor productivity x_t chooses to work for h_t hours, its labor income is $w_t x_t h_t$, where w_t is the wage rate for the efficiency unit of labor. Households hold assets, a_t, that yield the real rate of return, r_t. The total (labor and capital) income is subject to a log-linear net tax function. A household maximizes its lifetime utility:

$$\max_{\{c_t,h_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{{c_t}^{1-\sigma} - 1}{1-\sigma} - B\frac{{h_t}^{1+1/\gamma}}{1+1/\gamma} \right\}$$

subject to

$$c_t + a_{t+1} - a_t = (1-\tau)(w_t x_t h_t + r_t a_t) + T(a_t, x_t),$$

$$a_{t+1} \geq \underline{a},$$

where c_t is consumption. Parameters σ and γ represent the relative risk aversion and labor-supply elasticity, respectively. Capital markets are incomplete in two senses: (i) physical capital is the only available asset for households to insure against idiosyncratic shocks to their productivity and (ii) households face an exogenous borrowing constraint $\underline{a}$: $a_{t+1} \geq \underline{a}$ for all t. Households differ *ex post* with respect to their productivity x_t and asset holdings a_t, whose cross-sectional joint distribution is characterized by the probability measure $\mu_t(a_t, x_t)$. There is an income tax whose rate is τ. $T(a_t, x_t)$ represents the transfer from the government, which depends on current income $y_t = w_t x_t h_t + r_t a_t$.

Firms: The representative firm produces output according to a constant-returns-to-scale Cobb-Douglas production function in capital, K_t, and effective units of labor, $L_t = \int h_t x_t d\mu$. Capital depreciates at the rate δ each period and the total factor productivity of the country is A:

$$Y_t = F(L_t, K_t) = A{L_t}^{\alpha}{K_t}^{1-\alpha}.$$

Government: The government operates a tax/transfer system and spends on government purchases, G_t, which do not directly enter into the household's utility function.[2] The government runs a balanced budget each period:

$$\tau \int \big(w_t x_t h(a_t, x_t) + r_t a_t\big)\, d\mu(a_t, x_t) = \int T(a_t, x_t)\, d\mu(a_t, x_t) + G_t.$$

Recursive Representation: It is useful to consider a recursive equilibrium. Let $V(a, x)$ denote the value function of a household with asset holdings a and productivity x. Then, V can be expressed as follows:

$$V(a, x) = \max_{c,h} \left\{ \frac{c^{1-\sigma} - 1}{1-\sigma} - B\frac{h^{1+1/\gamma}}{1+1/\gamma} + \beta \mathbb{E}\big[V(a', x')|x\big] \right\}$$

subject to

$$c + a' - a = (1-\tau)(wxh + ra) + T(a, x),$$

$$a' \geq \underline{a}.$$

Equilibrium: A stationary equilibrium consists of a value function, $V(a, x)$; a set of decision rules for consumption, asset holdings, and labor supply, respectively, $c(a, x)$, $a'(a, x)$, and $h(a, x)$; aggregate input, K and L; and the invariant distribution of households, μ(a,x), such that:

1. Individual households optimize: Given w and r, the individual decision rules $c(a, x)$, $a'(a, x)$, $h(a, x)$, and $V(a, x)$ solve the Bellman equation.

2. The representative firm maximizes profits:

$$w = \alpha A(K/L)^{1-\alpha}$$

$$r + \delta = (1-\alpha)A(K/L)^{-\alpha}.$$

3. The goods market clears:

$$\int \big\{a'(a, x) + c(a, x)\big\} d\mu + G = F(L, K) + (1-\delta)K.$$

[2] We use government purchase, G, as a vehicle (i.e., residual spending) to achieve the balanced budget of the government in the long run.

4. The factor markets clear:

$$L = \int xh(a,x)d\mu$$
$$K = \int ad\mu.$$

5. The government balances the budget:

$$\tau \int \big(wxh(a,x) + ra\big)\, d\mu(a,x) = \int T(y(a,x))\, d\mu(a,x) + G.$$

6. Individual and aggregate behaviors are consistent: For all $A^0 \subset \mathcal{A}$ and $X^0 \subset \mathcal{X}$,

$$\mu(A^0, X^0) = \int_{A^0, X^0} \left\{ \int_{\mathcal{A},\mathcal{X}} \mathbf{1}_{a'=a'(a,x)} d\pi_x(x'|x) d\mu \right\} da' dx'.$$

2.2. Calibration

Since the Aiyagari-type model has been widely used in various macroeconomic analyses, we adopt the standard values for most parameters. The time unit is one year. The labor-income share, α, is 0.64, and the annual depreciation rate of capital, δ, is 10%. Workers are not allowed to borrow, so $\underline{a} = 0$. As is common in the macroeconomic literature, the relative risk aversion, σ, is assumed to be one (i.e., the log utility in consumption) to be consistent with the balanced growth path.[3] The Frisch elasticity of labor supply, γ, is set to 0.5, close to the estimates in the literature (e.g., Keane (2011), Chetty et al. (2011)). We assume that individual productivity x follows an AR(1) process: $\ln x' = \rho \ln x + \varepsilon_x$, where $\varepsilon_x \sim N(0, \sigma_x^2)$. We assume that $\rho = 0.91$, a commonly used value. The chosen value of σ_x for the U.S. is 0.21, which is an estimate provided by Floden and Lindé (2001) based on the Panel Study of Income Dynamics. In the benchmark economy, there are no taxes and transfers. Finally, the time discount factor, β, is set so that the real interest rate is 4%, which is the average real rate of return to capital

[3] Chetty (2006) argues that a mean estimate of the risk aversion is close to one. Gandelman and Hernández-Murillo (2015) estimate the coefficient of risk aversion for 75 countries and argue that the coefficient varies closely around one. Among the OECD countries, the null hypothesis of the coefficient log utility is rejected in only one country (S. Korea).

in the U.S. for the post-World War II period. We also choose the disutility from working B to generate average hours of work of 0.33 in the steady state. Table 1 summarizes the parameter values of the benchmark model economy.

Table 1: Parameters of the Benchmark Economy

α	0.64	Labor share in production function
δ	0.10	Depreciation rate of captial
β	0.948	Time discount factor
σ	1.00	Relative risk aversion
γ	0.50	Labor supply elasticity
B	22.5	Disutility from working
ρ	0.91	Persistence of idiosyncratic productivity
σ_x	0.21	S.D. of innovation to productivity shock

Column (1) of Table 3 reports the steady state of the benchmark economy. The Gini coefficients of income and wealth are 0.334 and 0.639, respectively. While the model exhibits significant dispersions in income and wealth, they are considerably smaller than those in the data (for example, 0.53 and 0.76, according to the Panel Study of Income Dynamics and 0.63 and 0.78, according to the Survey of Consumer Finances). This is inevitable given that the model is driven by a single source of heterogeneity (i.e., an idiosyncratic productivity shock). It is well known (see, for example, Diaz-Gimenez et al. (1997)) that this type of model is not able to account for the concentration found in, say, the upper 1% of the income or wealth distribution. However, it is not our primary interest to account for the likes of Bill Gates, and so we do not focus on the extreme upper part of the wealth distribution. We would like to do a simple comparison of UBI vs. NIT in a simple heterogeneous agent model with general equilibrium effects.

2.3. Experiment 1: Mankiw-Like Programs

The spirit of the exercise is to mimic Mankiw's example as closely as possible. In the U.S., the median and mean household incomes (as of 2018) are $61,937, and $87,864, respectively. Thus, the pivotal income where the net tax (= tax - transfer) is zero in Mankiw's example, \$60,000, is close to the median income. In our benchmark economy, the median and mean incomes are 0.346 and 0.435, respectively. We will use the median income of the benchmark economy as the pivotal income level $\hat{y} = 0.346$.

Table 2: Structure of Redistribution Programs

Variable	Mankiw		Mankiw-Like		Balance Budget		
	UBI	NIT	UBI	NIT	UBI	NIT	NIT
Pivotal Income ($\hat{y}$)	\$60,000		0.3460		0.3920		0.3210
Transfer for $y = 0$ (T_0)	\$12,000		0.0692		0.0783		0.0642
Tax Rate (τ)	0.2	0.2	0.2	0.2	0.2	0.2	0.074
Phase-out Rate (ϕ)	–	0.2	–	0.2	–	0.2	0.2

Note: In NIT, the phase-out rate applies to income below $\hat{y}$ and the tax rate applies to income above $\hat{y}$.

First, consider the universal basic income program where everyone receives T_0 which is 20% of the median income in the benchmark economy: $T_0 = 0.2 \times \hat{y} = 0.2 \times 0.346 = 0.0692$. As in Mankiw's example, the government levies a flat tax rate of 20% ($\tau = 0.2$) on total income.

In the negative income tax program, we assume that (i) households with zero income receive the same $T_0 = 0.0692$ and (ii) that the transfer amount phases out at 20% ($\phi = 0.2$) for every dollar earned until $\hat{y}$. That is, the government transfer $T(y) = T_0 - \phi y$, if $y < \hat{y}$, and $T(y) = 0$, otherwise. For income above $\hat{y}$, the government levies a flat tax rate of 20% ($\tau = 0.2$). Table 2 summarizes the redistribution programs we consider.

Column (2) of Table 3 reports the new steady state of the model economy under this UBI system. Aggregate output decreases by 12% (from 0.585 to 0.515) in the long run. Capital and labor decrease by 21% and 9%, respectively. There are two forces behind these decreases of factor inputs. First, introduction of the UBI reduces the motive for precautionary saving and labor supply. Second, the imposition of an income tax reduces the incentive to work and save. Since capital decreases more than labor, the capital-labor ratio falls and the equilibrium interest rate rises to 5.45% (and the wage rate falls), which slightly increases the Gini coefficients of wealth and (before-tax) income. Thanks

Table 3: Steady States

	(1)	(2)	(3)	(4)	(5)	(6)
	Benchmark	Mankiw-Like		Balanced Budget		
		UBI	NIT	UBI	NIT	NIT
Tax Rate (τ)	0	0.2	0.2	0.2	0.2	0.074
Phase-out Rate (ϕ)	–	–	0.2	–	0.2	0.2
Pivotal Income ($\hat{y}$)	–	**0.346**		**0.392**		**0.321**
Transfer at $y = 0$ (T_0)	–	0.0692		0.0783		0.0642
Output	0.585	0.515		0.510		0.547
Capital	1.520	1.200		1.186		1.345
Hours Worked	0.332	0.304		0.301		0.312
Effective Labor	0.344	0.320		0.317		0.33
Wage	1.088	1.030		1.029		1.061
Interest Rate	4.00%	5.45%		5.48%		4.65%
Income						
Mean	0.435	0.395		**0.392**		0.413
Median	**0.346**	0.311		0.295		**0.329**
Before-Tax Gini	0.324	0.339		0.341		0.346
After-Tax Gini	0.324	0.278		0.273		0.309
Wealth Gini	0.639	0.653		0.657		0.675
Tax/GDP	0.00	0.153	0.046	0.153	0.038	0.02
Transfer/GDP	0.00	0.134	0.027	0.153	0.038	0.02
Surplus/GDP	0.00	0.019		0.000	0.000	0.00
Welfare (CEV)	–	-2.85%		-0.27%		0.31%

Note: The median-mean income ratio is 0.7 in the U.S. The income and wealth Ginis are 0.53 and 0.76, respectively, according the PSID. They are 0.63 and 0.78, according to the SCF.

to the redistribution policy, the after-tax income Gini drops from 0.324 to 0.278. As aggregate output decreases significantly, average income also falls. The UBI program requires about 13.4% of GDP, whereas the total tax revenue is 15.3% of the GDP, resulting in a government budget surplus. In this simulation, we assume that government purchase G(1.9% of GDP), which does not enter the utility function of households directly, fills the gap. Overall, despite a strong redistribution through the universal basic income program, average welfare worsens by 2.85% (because of high tax and wasted resources, G).

Now let's compare the negative income tax (NIT) with the same marginal tax rate. While the UBI and NIT appear to provide the same economic incentives in this example, they will not be identical in practice. First, the balanced budget of the program is not guaranteed, unless the average income is exactly $\hat{y}$ in the new steady state. Both the average and the median incomes decrease by about 10% when we introduce a redistribution program (either UBI or NIT). The average income is 0.395 and the median income is 0.311, according to the long-run equilibrium of the model. Thus, our pivotal income (which was the median income in the benchmark economy), 0.346, falls between the median and average incomes in the presence of a redistribution program. Here, we assume that G (which does not enter the utility of households) fills the gap between government expenditure and tax revenue. While both programs provide identical economic incentives to households, the government budget for the NIT is only one-fifth that for the UBI. Although our model abstracts from any administrative cost of running a redistribution program, a welfare program may be associated with non-negligible administrative costs in practice.

2.4. Experiment 2: Balanced-Budget Programs

The above example does not guarantee the balanced budget of the government unless the average income is exactly the same as the pivotal income. Let's compare two programs where the budget is balanced ($G = 0$). There are many different ways to implement a budget-balanced program. One way to achieve a balanced budget (under the flat income tax rate) is to set the pivotal income exactly at the average income of the economy. Let's assume that households with zero income receive 20% of the pivotal income $T_0 = 0.2 \times \hat{y}$. Columns (4) and (5) of Table 3 report the long-run equilibria of the UBI and the NIT. Aggregate output, capital, and hours worked are slightly lower than those in Experiment 1. Again, the UBI and the NIT, by construction, provide the same incentives to households. The average welfare is slightly worse (-0.27%) than the benchmark but higher than those in Experiment 1 (because no resources are wasted, $G = 0$). Again, the UBI and the NIT result in an identical equilibrium in this experiment except for the size of the government: the tax-to-GDP ratio is 15.3% in the UBI vs. 3.8% in the NIT.

We next consider an NIT program where (i) the pivotal income is the median (instead of the average)–i.e., the government transfer is restricted to more needy households (and, as a result, requires a smaller tax revenue) and (ii) the income tax schedule is piece-wise linear (instead of a flat tax rate). Assume that the pivotal income is $\hat{y} = 0.321$, which is close to the median income in the new steady state. Given the same phase-out rate of $\phi = 0.2$ for transfers, we search for a tax rate (which will be applied to income levels above $\hat{y}$) that achieves a balanced budget. Column (6) of Table 3 shows that the required income tax rate for the balanced budget is now a much lower rate of 7.4% ($\tau = 0.074$) because transfers are restricted to more needy households. While long-run output, capital, and hours worked are still lower than those of the benchmark economy, the average welfare is slightly higher (by 0.31%) than that in the benchmark economy because of less distortion in the labor supply. Again, a UBI program can reproduce the identical outcome with the same transfer amount for everyone ($T_0 = 0.0642$) and a piece-wise linear income tax rate schedule (i.e., τ is 0.074 for market income below $\hat{y}$ and 0.2 for market income above $\hat{y}$). However, the tax-to-GDP ratio is much higher (11.7%) in the UBI (compared to a mere 2% in the NIT).

3. Summary

Based on a quantitative general equilibrium model (*a la* Aiyagari (1994)) we compare the two redistribution policies, negative income tax (NIT) and universal basic income (UBI), designed to provide identical economic incentives to households as in Mankiw (2020). According to the quantitative analysis, the UBI requires more taxes: the tax-to-GDP ratio is 15%, much higher than 3.8% in the NIT which provides identical economic incentives. Nevertheless, neither redistribution program improves social welfare significantly in the long run as the reduction in capital and labor (due to a smaller tax distortion and a weakened motive for precautionary saving and working) roughly offsets the insurance benefit. Average welfare slightly decreases, by 0.27%, in terms of consumption equivalence units. Aggregate output, capital, and hours worked decrease by 12%, 22%, and 10% in the long run because of reduced savings and labor supply.

When we consider a slightly modified program under which (i) the pivotal income is the median (instead of the average): the government transfer is restricted to more needy households (and, as a result, requires smaller tax revenue) and (ii) the income tax schedule is piece-wise linear (instead of a flat tax rate), social welfare slightly increases (by 0.31%) in the long run.

Finally, we raise a warning flag in applying our results to the real world. We have conducted our analysis under two restrictive assumptions: (i) All taxes are collected under a piece-wise linear income tax schedule and (ii) there are no administrative costs in collecting taxes and providing transfers. In a more realistic environment, the two policies (with the UBI requiring tax revenue nearly 5 times as large as that of the NIT) may generate very different outcomes. For example, the administrative cost of collecting taxes is 1.1% of the net tax revenue on average across OECD countries (OECD (2013)). Eurostat (2012) reports that the administrative cost of social welfare programs is about 3% of the total budget.

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