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# CLASSIC POLICY BENCHMARKS FOR HETEROGENEOUS AGENT ECONOMIES

**James Bullard**, Federal Reserve Bank of St. Louis

**Riccardo DiCecio**, Federal Reserve Bank of St. Louis

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# Introduction

## LARGE-SCALE HETEROGENEOUS AGENT DSGE

- There has been increasing interest in large-scale heterogeneous agent DSGE models.
  - These models have realistic degrees of heterogeneity—approaching observed Gini coefficients in U.S. data.
  - They more directly address issues around income, financial wealth and consumption inequality.
  - What is the role of monetary policy?

## OUTLINE OF THE ARGUMENT

- We construct a heterogeneous agent economy featuring:
  - An aggregate shock to the natural rate of interest
  - Both permanent and temporary idiosyncratic risk at the household level
  - A simple and symmetric structure
- We include four policymakers:
  - A monetary authority
  - A fiscal authority
  - A labor market authority
  - An education authority
- We describe a competitive equilibrium in which the four policymakers act in concert to attain a first-best allocation of resources.

## A CLASSIC VIEW

- The policymaker roles are “classic.”
  - The monetary authority follows a state-contingent policy rule reacting to the aggregate shock (nominal GDP, or NGDP, targeting).
  - The fiscal authority raises revenue via a non-state contingent linear labor income tax on all households.
  - The labor market authority runs an unemployment insurance program.
  - The education authority minimizes the variance of beginning-of-life human capital endowments.
- *Hence, the main result is that classic policy prescriptions can achieve the first-best allocation of resources in this benchmark heterogeneous agent economy.*
  - This result may be helpful in understanding more complicated economies that deviate from this benchmark.

## SOME SURPRISING FINDINGS

- The proposed classic policies appear broadly similar to actual policies in place in OECD economies.
- Simple linear labor income taxes can be used without distorting the labor supply.
- The fiscal authority does not rely on age-dependent taxation in this environment.
- The best policy combination drives the consumption Gini to zero but leaves income and financial wealth Ginis close to observed levels.
  - This suggests that most observed income and financial wealth inequality is due to life-cycle effects alone.
- The model has a paper-and-pencil solution despite the aggregate shock.

## SOME RECENT LITERATURE

- Kaplan, Moll and Violante (*AER*, 2018):
  - NK model with heterogeneous households (HANK); reasonable Gini coefficients.
  - The monetary policy transmission mechanism is substantially altered relative to standard models.
- Bhandari, Evans, Golosov and Sargent (*Working paper*, NBER, 2018):
  - Incomplete markets, nominal friction, heterogeneous households; reasonable Gini coefficients.
  - Ramsey-optimal monetary-fiscal policy is substantially altered relative to standard models.
- Bullard and DiCecio (Unpublished manuscript, 2019):
  - Incomplete markets, nominal friction, heterogeneous households; reasonable Gini coefficients.
  - Optimal monetary-fiscal policy looks like classic prescriptions from standard models.

## ADDITIONAL RECENT LITERATURE

- Heathcote, Storesletten and Violante (*Working paper, NBER, 2019*):
  - Incomplete markets, real economy, heterogeneous households.
  - Optimal fiscal policy: The average marginal tax rate is increasing and concave in age; tax progressivity is U-shaped in age.
- Heathcote and Tsujiyama (*Unpublished manuscript, 2017*):
  - Incomplete markets, heterogeneous households.
  - Optimal Mirrleesian taxation is compared with parametric Ramsey taxation.
- Koenig (*IJCB, 2013*) and Sheedy (*BPEA, 2014*):
  - NGDP targeting in economies with nominal contracting.
- Huggett, Ventura and Yaron (*AER, 2011*):
  - The majority of life cycle earnings are attributable to age-23 characteristics as opposed to subsequent shocks.

# Environment

## LIFE-CYCLE MODELS

- We construct a general-equilibrium life-cycle economy with “symmetry assumptions.”
  - Each period, a new continuum of households enters the economy, makes economic decisions over the next 241 periods, then exits the economy. The model is therefore “quarterly.”
  - All households have log preferences defined over consumption and leisure—period utility is of the form

$$\eta \ln c + (1 - \eta) \ln \ell. \quad (1)$$

- All households have a discount factor of unity.
- The aggregate production technology is linear in the aggregate effective labor input.
- Aggregate shock: The economy grows over time via stochastic growth in total factor productivity.

## LIFE-CYCLE PRODUCTIVITY

- Each household is randomly assigned a personal productivity profile  $e = \{e_0, e_1, \dots, e_{240}\}$  when it enters the model.
  - Profiles are symmetric—they begin low, rise and peak exactly in the middle of life, then decline symmetrically back to the low level.
  - Profiles are restricted to be consistent with interior solutions to all household problems—households will choose to work low hours but not zero.
  - Profiles are members of a set  $\mathcal{E}$ , but in this talk we restrict  $\mathcal{E}$  to have just one member.
  - Households also draw a scaling factor  $\zeta$  from a lognormal distribution as they enter the model, i.e.,  $\ln \zeta \sim \mathcal{N}(\mu, \sigma^2)$ .
    - The product of their scaling factor and their assigned productivity profile permanently determines their life-cycle productivity, that is,  $\zeta e$ .
    - Accordingly, there will be arbitrarily rich and arbitrarily poor households in the economy.
  - For illustrative purposes,  $\zeta$  is drawn from a uniform distribution  $U[a, b]$  in the figures shown later.

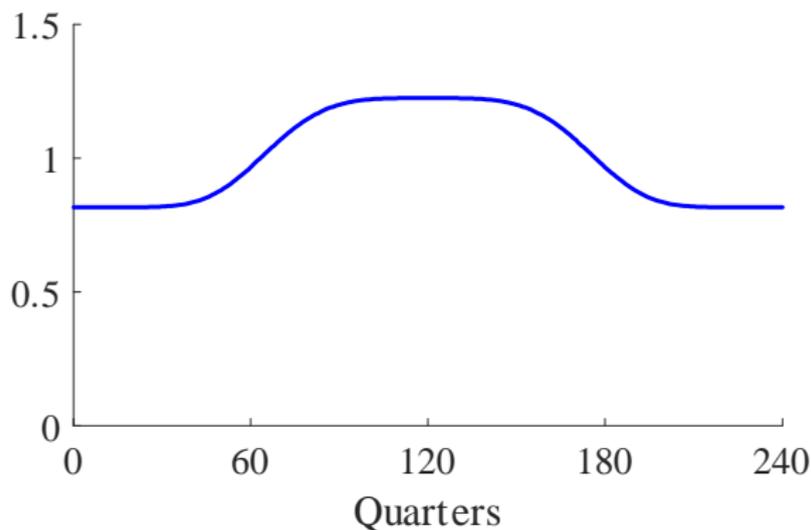
## RATIONALE FOR A PERMANENT PRODUCTIVITY SHOCK

- The assignment of productivity profiles is a stand-in for the human capital development that takes place before age 20 in actual economies, including schooling, parenting and any job experience before age 20.
- Huggett, Ventura and Yaron (*AER*, 2011) argue that differences in initial conditions are more important than subsequent shocks in explaining lifetime income.

## ADDITIONAL IDIOSYNCRATIC RISK

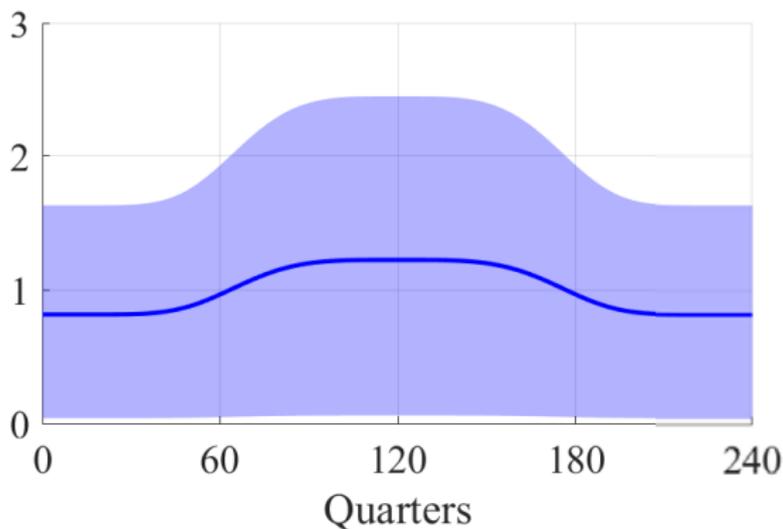
- Households can earn income in a competitive economywide labor market by supplying hours along with the productivity they have available at that date.
- At the beginning of each period, each household may be randomly unemployed.
- The household earns no income from work on dates of unemployment.
- The unemployment probability is *i.i.d.* and uncorrelated with the aggregate shock.

## BASELINE LIFE-CYCLE PRODUCTIVITY



**FIGURE:** A baseline personal productivity endowment profile. The profile is symmetric and peaks in the middle period of the life cycle at a level about 50% greater than at the beginning or end. A full model would include a set of symmetric profiles with differing shapes.

## THE MASS OF LIFE-CYCLE PRODUCTIVITY



**FIGURE:** The mass of endowment profiles with the scaling factor drawn from a uniform distribution  $U [0.05, 1.95]$ . Drawing from a lognormal distribution is harder to visualize, but such a distribution would include arbitrarily rich and arbitrarily poor households. The endowment Gini is about 35%.

## HOUSEHOLD CREDIT

- The overlapping-generations structure creates a large private credit market essential to good macroeconomic performance.
- The key asset is therefore *privately issued* household debt.
- As practical motivation, think of privately issued debt = “mortgage-backed securities.”
  - U.S. household debt in the first quarter of 2019 was about \$13.5 trillion, which was equal to about two-thirds of GDP.

## NON-STATE CONTINGENT NOMINAL CONTRACTING

- There is a key friction in the credit market: non-state contingent nominal contracting.
- There are two aspects to this assumption.
  - The non-state contingent aspect means that real resources are misallocated via this friction.
  - The nominal aspect means that the monetary authority may be able to fix the distortion to the equilibrium through appropriate monetary policy.

## INFORMATION ASSUMPTIONS

- All households have private information concerning their scaling factor  $\xi$  and their productivity profile drawn from the (singleton) set  $\mathcal{E}$ .
- Households can choose a level of effort, or intensity of work, which is linear in the life-cycle productivity profile.
  - Accordingly, households can potentially pretend to possess lower productivity profiles than they actually have.
- The unemployment draw is public information.

## ADDITIONAL ASSUMPTIONS

- There are no borrowing constraints.
  - See Azariadis et al. (*JEDC, 2019*) for a version with some households excluded from credit markets.
- There is no population growth in this version.
- There is no default.
- Prices are flexible.
- Capital is fixed.
- We ignore the effective lower bound in this version; see Azariadis et al. (*JEDC, 2019*).
- All policies are set credibly for all time  $t \in (-\infty, +\infty)$ .

# Four Policymakers

## FOUR POLICYMAKING ENTITIES

- There are four policymaking entities.
  - The monetary authority can observe the aggregate shock at the beginning of date  $t$  and then set the price level  $P(t)$ .
  - The fiscal authority can set taxes on labor or capital income to raise an exogenously specified fraction of available real output.
  - The labor market authority observes household-specific unemployment shocks, sets taxes and provides household-specific transfers.
  - The education authority can control the initial dispersion of life-cycle productivity profiles by controlling the variance of the scaling factor  $\xi$ .

## THE PROPOSED POLICY MIX

- The proposed policy mix is as follows:
  - The monetary policymaker follows an NGDP targeting rule similar to Koenig (*IJCB, 2013*) and Sheedy (*BPEA, 2014*).
  - The fiscal authority sets a linear tax on all labor income earned that is sufficient to meet its revenue requirement.
  - The labor market authority sets a linear tax on all labor income earned that is sufficient to provide appropriate transfers to unemployed households.
  - The education authority minimizes the dispersion of life-cycle productivity profiles by setting  $\zeta = 1$ .

## THE WICKSELLIAN NATURAL REAL RATE OF INTEREST

### THEOREM

*Under the proposed policy mix, the real interest rate is exactly equal to the stochastic aggregate output growth rate at every date, and an equal-treatment social planner that discounts at this rate will conclude that this is a social optimum.*

### COROLLARY (EQUITY SHARE CONTRACTING)

*Any two households that share the same productivity profile consume the same amount at each date, and consumption growth is equalized for all households.*

### COROLLARY

*Desired labor supply over the life cycle depends on the shape of the productivity profile alone.*

# Characterizing the Policies

## CHARACTERIZING THE POLICIES

- We first describe how the monetary policy works.
- We then characterize the equilibrium in a series of schematic graphs representing the cross-sectional distribution of households at each date.
- In the graphs, we will show both the case when  $\xi = 1$ , the social optimum, and also the case where  $\xi$  is drawn from a uniform distribution.
  - We can interpret this latter case as one where the education policymaker cannot drive the variance the scaling factor all the way to zero.

## MONETARY POLICY

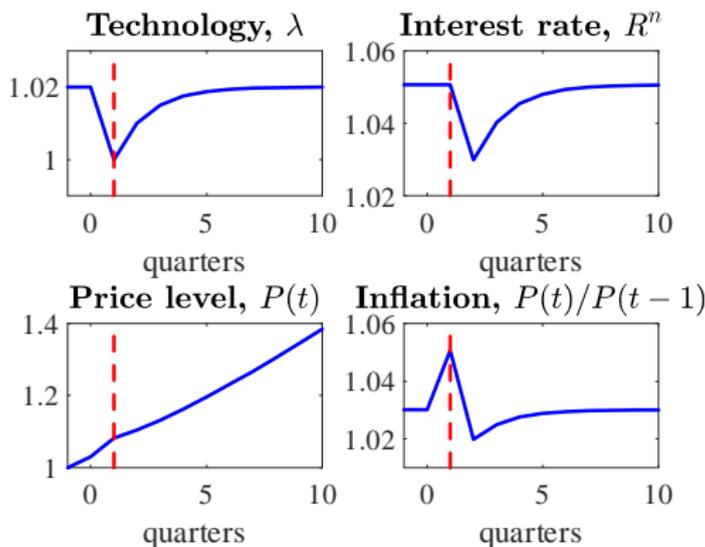
- The monetary policymaker controls the price level  $P(t)$  directly and follows an NGDP targeting rule similar to Sheedy (*BPEA, 2014*), Koenig (*IJCB, 2013*) and Bullard and DiCecio (*Working paper, St. Louis Fed, 2019*):

$$P(t) = \frac{R^n(t-1, t)}{\lambda(t-1, t)} P(t-1), \quad (2)$$

where  $R^n(t-1, t)$ , the gross nominal interest rate, is equal to the expected gross rate of NGDP growth between dates  $t-1$  and  $t$ , and  $\lambda(t-1, t)$  is the realized gross rate of aggregate productivity growth between dates  $t-1$  and  $t$ .

- The NGDP targeting rule works because it provides a form of insurance for all households against future aggregate shocks.
  - This policy rule is not unique. See Bullard and Singh (*JMCB, 2019 forthcoming*).

## EFFECTS OF AN AGGREGATE SHOCK



**FIGURE:** Monetary policy responds to a decrease in aggregate productivity growth by increasing the inflation rate in the period of the shock. Subsequently, however, inflation converges to its long-run equilibrium value from below. The nominal interest rate drops in the period after the shock.

## LEISURE CHOICES AND TAX POLICY

- Given the monetary policy, the labor market authority sets a tax  $\tau^u$  that is linear in labor earnings.
- The fiscal authority sets a tax  $\tau^f$  that is also linear in labor earnings.
- The household  $i$  first-order condition for leisure can then be written as

$$\ell_{t,i}(t+s) = (1-\eta) \frac{\bar{e}_i}{e_{s,i}} = (1-\eta) \frac{\bar{e}}{e_s}, \quad \forall i, \quad (3)$$

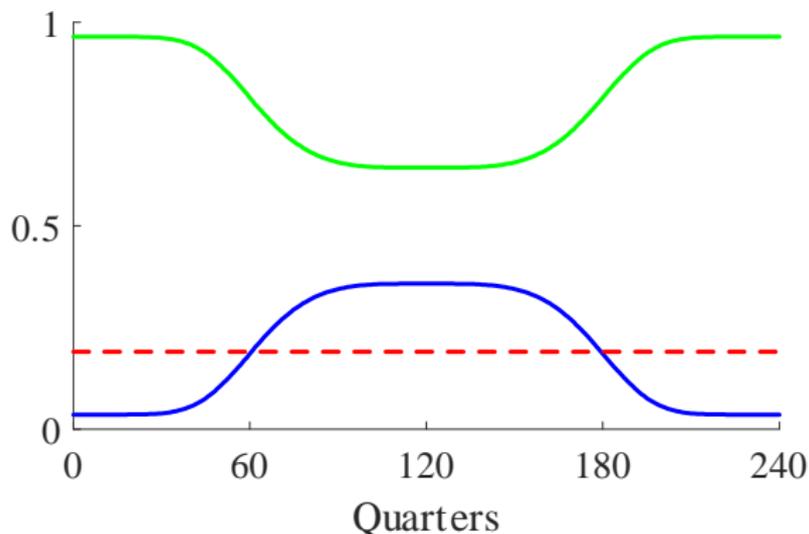
where  $\bar{e} = \frac{1}{T+1} \sum_{s=0}^T e_s$  and  $\bar{e}_i = \frac{1}{T+1} \sum_{s=0}^T e_{s,i}$ .

- The scaling factor  $\zeta$  and the two taxes  $\tau^u$  and  $\tau^f$  are all linear in  $e$  and therefore cancel out in this expression—so taxing in this manner is nondistortionary.
- This result requires that all labor income is taxed at these rates.

## LEISURE CHOICES AND MIRRLEESIAN CONSIDERATIONS

- Because  $\tau_i^u = \tau^u \forall i$  and  $\tau_i^f = \tau^f \forall i$ , households will not be incentivized to withhold effort by misrepresenting their type.
- Under these policy choices, all households choose the same leisure and hours worked profile over the life cycle, and aggregate output is as large as it would be in an economy without taxation.

## HOURS WORKED OVER THE LIFE CYCLE



**FIGURE:** Cross section: Leisure decisions (green), labor supply decisions (blue) and fraction of work time in U.S. data, 19% (red). The labor/leisure choice depends on age only. High-income households plan to work the same hours as low-income households at each age. A certain percentage of the continuum of households in each cohort is unemployed but insured.

## EDUCATION POLICY

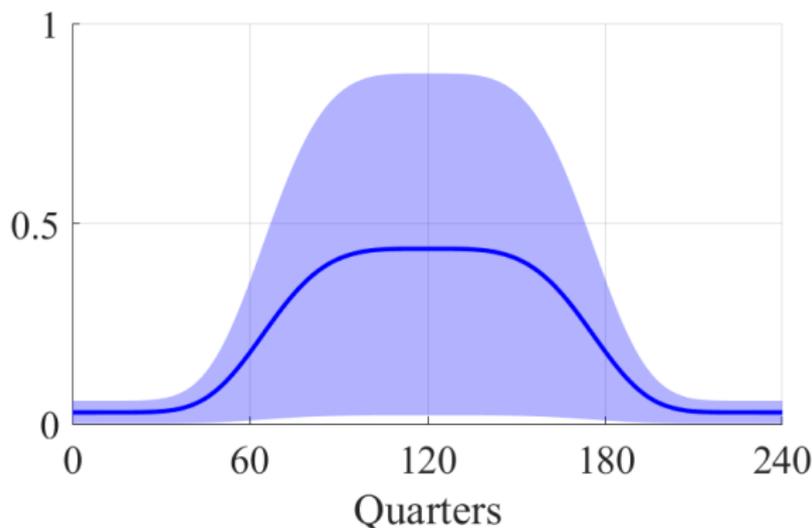
- “Education policy” influences the productivity profile dispersion parameter  $\sigma$ .
- One could interpret this as an idealized insurance market that operates before households enter the economy at age 20.
- Limiting case:  $\sigma = 0$ , all households receive the same profile.
- This would be a “perfectly equal” economy in that the talent distribution would collapse to just one life-cycle pattern.
  - This would drive the consumption Gini to zero.
  - However, the income and wealth Gini coefficients would remain close to observed values—these are driven mostly by the life-cycle structure.
- We will show both the idealized case and cases where  $\sigma > 0$ .

# Characterizing the Equilibrium

## LABOR INCOME

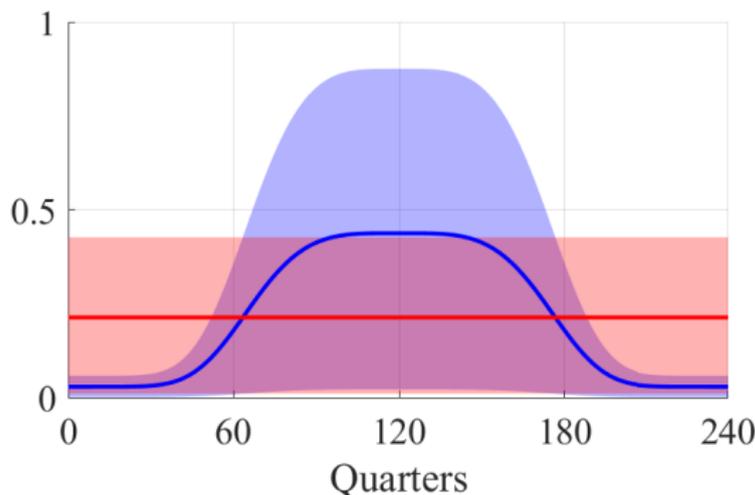
- Households want to work more when they are in their peak earning years in the middle of the life cycle.
- This creates substantial labor income inequality.

## LABOR INCOME MASS



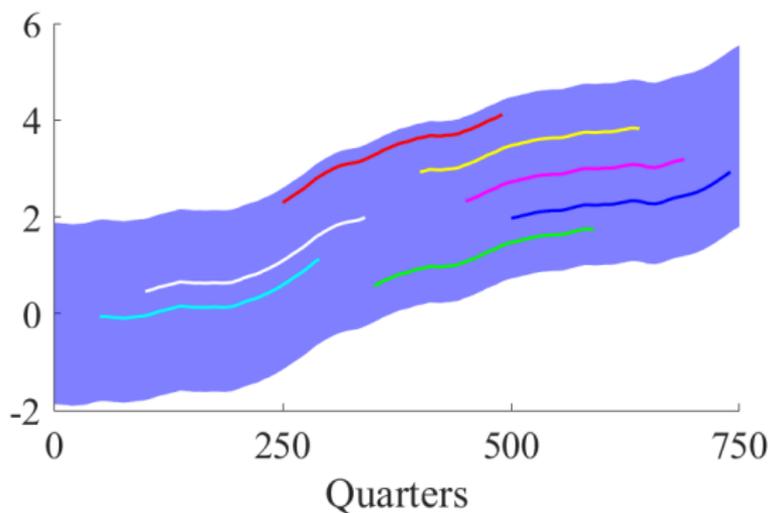
**FIGURE:** Cross section: Labor income profiles with unemployment insurance. Personal productivity peaks at the middle of the life cycle, and households work more at that time as well, making income even more concentrated in the peak earning years. The blue line depicts conditions of the theorem with  $\xi = 1$ .

## CONSUMPTION MASS



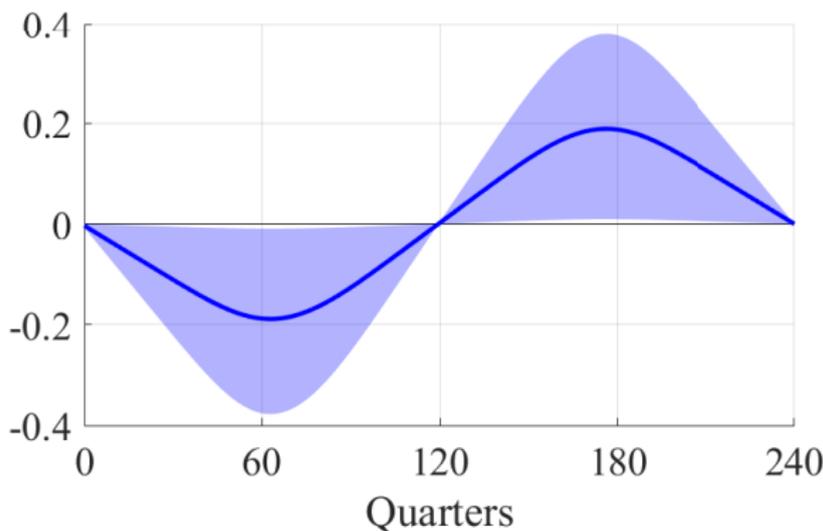
**FIGURE:** Cross section: Schematic consumption mass (red) and labor income mass (blue). Under optimal monetary policy, the private credit market reallocates uneven labor income into perfectly equal consumption along each productivity profile. The consumption Gini is 31.7%, similar to values calculated from U.S. data. The blue line depicts conditions of the theorem with  $\zeta = 1$ .

## CONSUMPTION EVOLUTION



**FIGURE:** Time series: Evolution of the distribution of log consumption (shaded area) and examples of individual log consumption profiles (colored lines). Under optimal monetary policy, individual consumption profiles share the same stochastic trend as aggregate consumption.

## NET ASSET HOLDING MASS

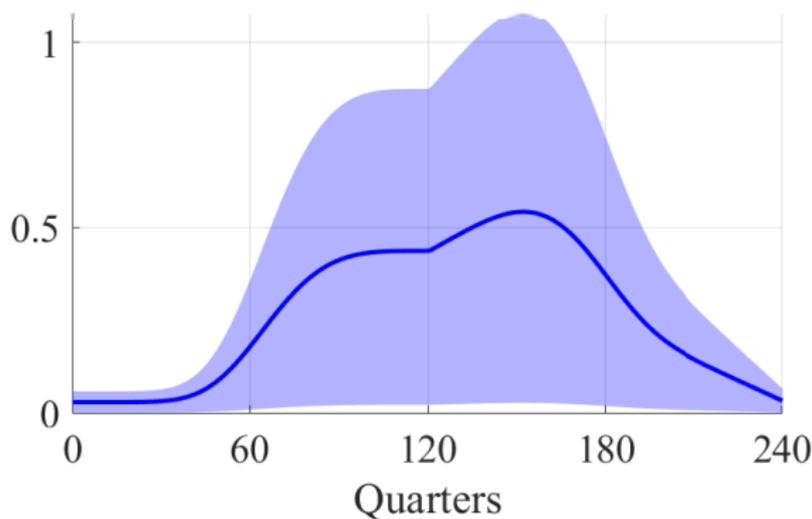


**FIGURE:** Cross section: Schematic net asset holding mass relative to GDP by cohort. Borrowing, the negative values to the left, peaks at stage 60 of the life cycle (age ~35), while positive assets peak at stage 180 of life (age ~65). The financial wealth Gini is 72.7%, similar to values calculated in U.S. data. The blue line depicts conditions of the theorem with  $\xi = 1$ .

## THREE NOTIONS OF INCOME

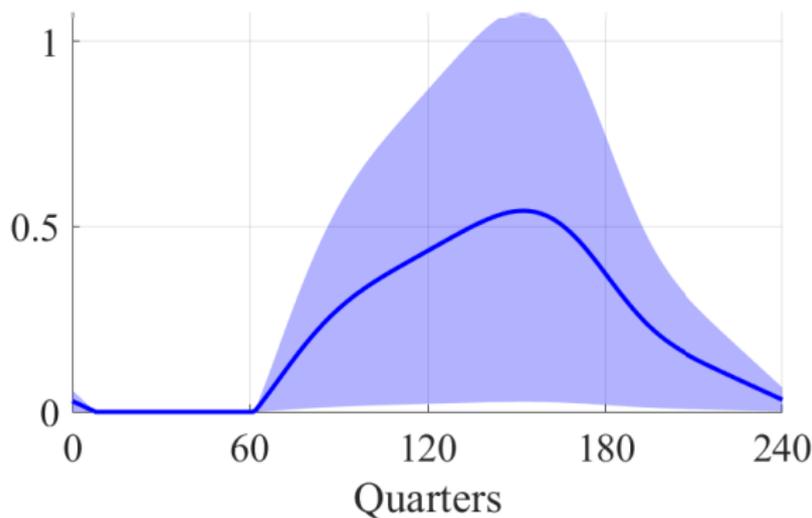
- Three notions of income:
  - Pretax labor income,  $Y_1$ .
  - Pretax labor income plus non-negative capital income,  $Y_2$ .
  - The non-negative component of total income,  $Y_3$ .
- Gini coefficients of income distributions:  $G_{Y_1} = 56.1\%$ ,  $G_{Y_2} = 51.5\%$ ,  $G_{Y_3} = 59.5\%$ .

## LABOR INCOME + NON-NEGATIVE CAPITAL INCOME



**FIGURE:** Cross section: Profiles of labor income and non-negative capital income. The blue line depicts conditions of the theorem with  $\zeta = 1$ .

## NON-NEGATIVE TOTAL INCOME



**FIGURE:** Cross section: Profiles of non-negative total income. The blue line depicts conditions of the theorem with  $\zeta = 1$ .

# Inequality

## DATA ON INEQUALITY IN THE U.S.

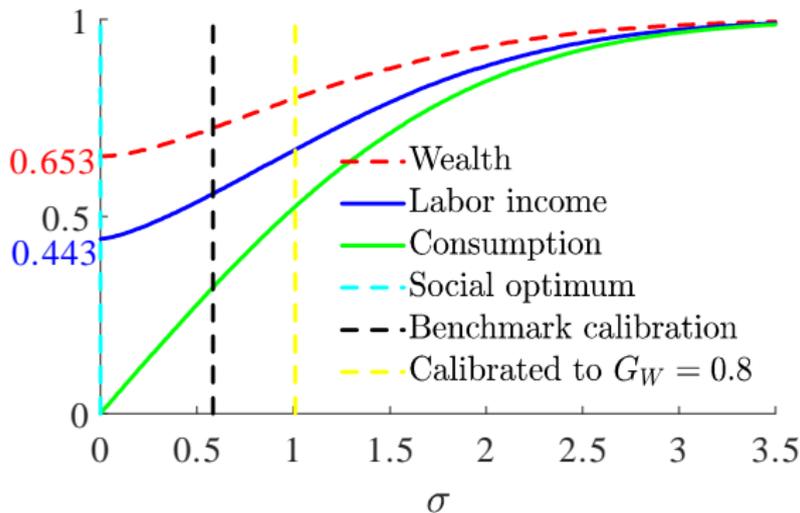
- Consumption (Heathcote, Perri and Violante, *RED, 2010*):  $G_{C,U.S.} = 32\%$ .
- Income (CBO, 2016): pre-taxes/transfers  $G_{Y,U.S.} = 51\%$ ;  
post-taxes/transfers  $G_{Y,U.S.} = 43\%$ .
- Financial wealth (Davies, Sandström, Shorrocks and Wolff, *EJ, 2011*):  $G_{W,U.S.} = 80\%$ .

## GINI COEFFICIENTS

	<b>Wealth</b> W	$Y_1$	<b>Income</b> $Y_2$	$Y_3$	<b>Consumption</b> C
U.S. data	80%		51%		32%
Uniform	72.7%	56.1%	51.5%	59.5%	31.7%
Lognormal	72.4%	55.7%	51.1%	59.0%	32%

**TABLE:** Gini coefficients in the U.S. data and in the model with uniform and lognormal productivity.

## PRODUCTIVITY DISPERSION AND GINI COEFFICIENTS



**FIGURE:** As the dispersion of productivity profiles,  $\sigma$ , increases, the Gini coefficients increase. The ordering  $G_W > G_Y > G_C$  is preserved. The case where  $\sigma = 0$  is the social optimum and has  $G_C = 0$  but  $G_W = 65.3\%$  and  $G_Y = 44.3\%$ . The model can match the wealth Gini in the data with a sufficiently large choice of  $\sigma$ .

# Conclusions

## SUMMARY

- A classic combination of policies, which looks like those of many OECD countries, can deliver a first-best allocation of resources in this environment.
  - A monetary policymaker pursues NGDP targeting, providing a type of insurance against the aggregate shock.
  - This leaves labor supply as a function of relative life-cycle productivity alone. Therefore, this enables non-distortionary linear labor income taxes to fund government expenditures as well as an unemployment insurance program.
  - Education policy can mitigate the effects of the permanent shock to household productivity as households enter the model without impacting the other policy settings.
  - A perfect education policy could drive the consumption Gini to zero but would leave income and wealth Ginis near their observed values.
  - These classic benchmarks may be useful in understanding the effects of monetary policy for models in this class going forward.