Shocks, Frictions, and Inequality in US Business Cycles

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Background

- A new generation of monetary business cycle models has become popular featuring heterogeneous agents and incomplete markets(HANK models).

- Much of previous literature so far has focused on specific channels of transmission, shocks, or puzzles.

- This paper aims to answer three questions:

  (1) Do data on inequality change the estimated shocks and frictions driving the US business cycle?
  (2) How important are business cycle shocks for the evolution of US inequality?
  (3) How would inequality have developed if government business cycle policies had been different?

What this paper do

- This paper study the business cycle using a technique similiar to Smets and Wouters (2007), extending this technique to the analysis of HANK models;
- Specifically, estimate an incomplete markets model by a full information Bayesian likelihood approach using the state-space representation of the model
- To infer the importance of inequality for the business cycle, authors estimate the HANK model with and without data on inequality.
- To understand the impacts of business cycle shocks on US inequality, they used the method of historical decomposition and impluse respones function.

Model

- Modelling an economy composed of firm sector, household sector, and government sector.
- The firm sector comprises:
  (a) Intermediate goods producers;
  (b) Final goods producers;
  (c) Producers of capital goods;
  (d) Labor packers that produce labor services;
  (e) Unions that differentiate raw labor rented out from households

Households

- The household sector is subdivided into two types of agents: workers and entrepreneurs.
- The transition between both types is stochastic.
- Both rent out physical capital, but only workers supply labor. Entrepreneurs do not work, but earn all pure rents;

Households

- Efficiency of a worker's labor evolves randomly exposing worker-households to labor-income risk;
- All households self-insure against the income risks they face by saving in a liquid nominal asset (bonds) and a less liquid asset (capital);
- Trading illiquid assets is subject to random participation in the capital market;

Households

- A household's gross labor income $w_t n_{it} h_{it}$ is composed of the aggregate wage w_t, the hours worked n_{it}, and idiosyncratic labor productivity h_{it};

$$\tilde{h}_{it} = \begin{cases} \exp\left(\rho_h \log \tilde{h}_{it-1} + \epsilon^h_{it}\right) & \text{with probability } 1-\zeta \text{ if } h_{it-1} \neq 0 \\ 1 & \text{with probability } \iota \text{ if } h_{it-1} = 0 \\ 0 & \text{else} \end{cases}$$

- where $h_{it} = \tilde{h}_{it} / \int \tilde{h}_{it} di$, to make sure that average worker productivity is constant.

- With probability ζ households become entrepreneurs, and with probability ι an entrepreneur returns to workers;

Households

- shocks ϵ^h_{it} to productivity are normally distributed with time-varying variance that follows a log-AR(1) process;
- The time-varying variance $\sigma^2_{h,t}$ could endogenously feedback to aggregate effective hours N_{t+1}:

$$\sigma^2_{h,t} = \bar{\sigma}^2_h \exp \widehat{s}_t$$
$$\widehat{s}_{t+1} = \rho_s \widehat{s}_t + \Sigma_Y \widehat{N}_{t+1} + \epsilon^\sigma_t$$

Households

- Entrepreneur obtains a fixed share of the pure rents (aside from union rents) Π_t^F from monopolistic competition in the goods sector and the creation of capital;
- Union rents, Π_t^U are distributed lump-sum across workers;
- Based on above assumption, the budget constraint of household should be:

$$c_{it} + b_{it+1} + q_t k_{it+1} = b_{it} \frac{R\left(b_{it}, R_t^b, A_t\right)}{\pi_t} + \left(q_t + r_t\right) k_{it} + z_{it} + \mathbb{I}_{h_{it} \neq 0} \Pi_t^U + \mathbb{I}_{h_{it} = 0} \Pi_t^F$$

where $z_{it} = \left(1 - \tau_t^L\right)\left(w_t h_{it} n_{it}\right)^{1-\tau_t^P}$, τ_t^L and τ_t^P determine the level and the progressivity of the tax code.

Households

- Holdings of bonds have to be above an exogenous debt limit $\underline{B}$, and holdings of capital have to be non-negative:

$$k_{it+1} \geq 0 \quad , \quad b_{it+1} \geq \underline{B}$$

- Assuming that there is a wasted intermediation cost that drives a wedge between the government bond yield R_t^b and the interest paid by/to households R_t, and such wedge follows:

$$R\left(b_{it}, R_t^b, A_t\right) = \begin{cases} R_t^b A_t & \text{if } b_{it} \geq 0 \\ R_t^b A_t + \bar{R} & \text{if } b_{it} < 0 \end{cases}$$

- shock A_t can be regarded as the “risk-premium shock” in Smets and Wouters (2007).

Households

- The decision-making problem of Household sector can be expressed as:

$$V_t^a(b,k,h) = \max_{k',b_a'} u\left[x\left(b,b_a',k,k',h\right)\right] + \beta \mathbb{E}_t V_{t+1}\left(b_a',k',h\right)$$

$$V_t^n(b,k,h) = \max_{b_n'} u\left[x\left(b,b_n',k,k,h\right)\right] + \beta \mathbb{E}_t V_{t+1}\left(b_n',k,h\right)$$

$$\mathbb{E}_t V_{t+1}\left(b',k',h\right) = \mathbb{E}_t\left[\lambda V_{t+1}^a\left(b',k',h\right)\right] + \mathbb{E}_t\left[(1-\lambda) V_{t+1}^n\left(b',k,h\right)\right]$$

- Value function V^a for the case where the household adjusts its capital holdings, the function V^n for the case in which it does not adjust.

Firm Sector - Labor sector

- Labor sector composed of unions and labor packers;
- Worker sell their labor services to a mass-one continuum of unions, and unions offers a different variety of labor to labor packers;
- Labor packers produce final labor services according to:

$$N_t = \left(\int \hat{n}_{jt}^{\frac{\zeta_t - 1}{\zeta_t}} \, dj \right)^{\frac{\zeta_t}{\zeta_t - 1}}$$

- Then each union faces a downward-sloping demand curve:

$$\hat{n}_{jt} = \left(\frac{W_{jt}}{W_t^F} \right)^{-\zeta_t} N_t$$

Firm Sector - Labor sector

- Unions have market power, they pay the households a wage lower than the price at which they sell labor to labor packers;
- They face a Calvo-type (1983) of adjustment friction with indexation, therefore maximize:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_w^t \frac{W_t^F}{P_t} N_t \left\{ \left(\frac{W_{jt}\bar{\pi}_W^t}{W_t^F} - \frac{W_t}{W_t^F} \right) \left(\frac{W_{jt}\bar{\pi}_W^t}{W_t^F} \right)^{-\zeta_t} \right\}$$

by setting W_{jt} in period t, and keeping it constant except for indexation to $\bar{\pi}_W$, the steady-state wage inflation rate.

Firm Sector - producer sector

- Intermediate goods are produced with a constant returns to scale production function:

$$Y_t = Z_t N_t^{\alpha} \left(u_t K_t\right)^{(1-\alpha)}$$

- Final goods producers differentiate a homogeneous intermediate good and set prices, they face a downward-sloping demand curve:

$$y_{jt} = \left(p_{jt}/P_t\right)^{-\eta_t} \; Y_t$$

- Price adjustment frictions à la Calvo (1983) with indexation, firms' managers maximize the present value of real profits given this price adjustment friction:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_Y^t \left(1 - \tau_t^L\right) \; Y_t^{1-\tau_t^P} \left\{ \left(\frac{p_{jt}\bar{\pi}_Y^t}{P_t} - \frac{MC_t}{P_t} \right) \left(\frac{p_{jt}\bar{\pi}^t}{P_t} \right)^{-\eta_t} \right\}^{1-\tau_t^P}$$

- Intermediate goods producer chooses optimal $\{K_t, N_t, u_t\}$ to minimize the cost, then we can obtain following conditions:

$$w_t^F = \alpha mc_t Z_t \left(\frac{u_t K_t}{N_t}\right)^{1-\alpha}$$

$$r_t + q_t\delta\left(u_t\right) = u_t(1-\alpha)mc_t Z_t \left(\frac{N_t}{u_t K_t}\right)^{\alpha}.$$

- where mc_t denotes the marginal cost of production and $q_t\delta(u_t)$ represents the cost from depreciation of capital.
- The optimality condition for utilization u_t is given by:

$$q_t\left[\delta_1 + \delta_2\left(u_t - 1\right)\right] = (1-\alpha)mc_t Z_t \left(\frac{N_t}{u_t K_t}\right)^{\alpha}$$

Firm Sector - Capital Goods Producers

- Capital goods producers take the price of capital q_t as given, they maximize:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t I_t \left\{ \Psi_t q_t \left[1 - \frac{\phi}{2} \left(\log \frac{I_t}{I_{t-1}} \right)^2 \right] - 1 \right\}$$

- where Ψ_t governs the marginal efficiency of investment which follows an AR(1) process in logs.
- Optimality of the capital goods production requires:

$$\Psi_t q_t \left[1 - \phi \log \frac{I_t}{I_{t-1}} \right] = 1 - \beta \mathbb{E}_t \left[\Psi_{t+1} q_{t+1} \phi \log \left(\frac{I_{t+1}}{I_t} \right) \right]$$

- the law of motion for aggregate capital follows:

$$K_t - (1 - \delta(u_t)) K_{t-1} = \Psi_t \left[1 - \frac{\phi}{2} \left(\log \frac{I_t}{I_{t-1}} \right)^2 \right] I_t$$

Government

- The government operates a monetary and a fiscal authority;
- Assuming that monetary policy sets the nominal interest rate following a Taylor-type (1993) rule with interest rate smoothing:

$$\frac{R^b_{t+1}}{\bar{R}^b} = \left(\frac{R^b_t}{\bar{R}^b}\right)^{\rho_R} \left(\frac{\pi_t}{\bar{\pi}}\right)^{(1-\rho_R)\theta_\pi} \left(\frac{Y_t}{Y^*_t}\right)^{(1-\rho_R)\theta_Y} \epsilon^R_t$$

- Government runs a budget deficit and hence accumulates debt governed by a rule (c.f. Woodford, 1995):

$$\frac{B_{t+1}}{B_t} = \left(\frac{B_t}{\bar{B}}\right)^{-\gamma_B} \left(\frac{\pi_t}{\bar{\pi}}\right)^{\gamma_\pi} \left(\frac{Y_t}{Y^*_t}\right)^{\gamma_Y} D_t, \quad D_t = D^{\rho_G}_{t-1} \epsilon^G_t$$

Government

- The government sets the average tax rate τ_t in the economy according to a similar rule:

$$\frac{\tau_t}{\bar{\tau}} = \left(\frac{\tau_{t-1}}{\bar{\tau}}\right)^{\rho_\tau} \left(\frac{B_t}{\bar{B}}\right)^{(1-\rho_\tau)\gamma_B^\tau} \left(\frac{Y_t}{Y_t^*}\right)^{(1-\rho_\tau)\gamma_Y^\tau} \epsilon_t^\tau$$

- Progressivity of the tax schedule τ_t^P evolves according to:

$$\frac{\tau_t^P}{\bar{\tau}^P} = \left(\frac{\tau_{t-1}^P}{\bar{\tau}^P}\right)^{\rho_P} \epsilon_t^P$$

- The level parameter of the tax code τ_t^L adjusts such that the average tax rate on income equals this target level:

$$\tau_t = \frac{\mathbb{E}_t\left(w_t n_{it} h_{it} + \mathbb{I}_{h_{it}=0}\Pi_t^F\right) - \tau_t^L \mathbb{E}_t\left(w_t n_{it} h_{it} + \mathbb{I}_{h_{it}=0}\Pi_t^F\right)^{\tau_t^P}}{\mathbb{E}_t w_t n_{it} h_{it} + \mathbb{I}_{h_{it}=0}\Pi_t^F}$$

Government

- Total taxes T_t are:

$$T_t = \tau_t \left(\mathbb{E}_t w_t n_{it} h_{it} + \mathbb{I}_{h_{it}=0} \Pi_t^F \right)$$

- and the government budget constraint determines government spending residually:

$$G_t = B_{t+1} + T_t - R_t^b / \pi_t B_t$$

- There are thus four shocks to government rules: monetary policy shocks ϵ_t^R, tax progressivity shocks ϵ_t^P, tax level shocks ϵ_t^τ, and structural deficit, i.e. government spending shocks, ϵ_t^G.

Market Clearing

- The bond market clears whenever the following equation holds:

$$B_{t+1} = B^d\left(R_t^b, A_t, r_t, q_t, \Pi_t^F, \Pi_t^U, w_t, \pi_t, \tau_t, \tau_t^P, \Theta_t, V_{t+1}\right)$$

$$:= \mathbb{E}_t\left[\lambda b_{a,t}^* + (1-\lambda) b_{n,t}^*\right]$$

- where $b_{a,t}^*, b_{n,t}^*$ are functions of the states (b, k, h), and depend on how households value in the future, $V_{t+1}(b, k, h)$, and the current set of prices $\left(R_t^b, A_t, r_t, q_t, \Pi_t^F, \Pi_t^U, w_t, \pi_t, \tau_t, \tau_t^P\right)$.
- The market for capital has to clear:

$$K_{t+1} = K^d\left(R_t^b, A_t, r_t, q_t, \Pi_t^F, \Pi_t^U, w_t, \pi_t, \tau_t, \tau_t^P, \Theta_t, V_{t+1}\right)$$

$$:= \mathbb{E}_t\left[\lambda k_t^* + (1-\lambda) k\right]$$

Equilibrium

- A sequential equilibrium with recursive planning in our model is a sequence of policy functions $\{x^*_{a,t}, x^*_{n,t}, b^*_{a,t}, b^*_{n,t}, k^*_t\}$, a sequence of value functions $\{V^a_t, V^n_t\}$, a sequence of prices $\{w_t, w^F_t, \Pi^F_t, \Pi^U_t, q_t, r_t, R^b_t, \pi_t, \pi^W_t, \tau_t, \tau^P_t\}$, a sequence of stochastic states $\{A_t, \Psi_t, Z_t\}$ and shocks $\{\epsilon^R_t, \epsilon^G_t, \epsilon^P_t, \epsilon^\tau_t, \epsilon^A_t, \epsilon^Z_t, \epsilon^\Psi_t, \epsilon^{\mu W}_t, \epsilon^{\mu Y}_t, \epsilon^\sigma_t\}$, aggregate capital and labor supplies $\{K_t, N_t\}$, distribution Θ_t over individual asset holdings and productivity, and expectations Γ for the distribution of future prices, such that:
- 1. Given the functional $\mathbb{E}_t V_{t+1}$ for the continuation value and period-t prices, policy functions $\{x^*_{a,t}, x^*_{n,t}, b^*_{a,t}, b^*_{n,t}, k^*_t\}$ solve the households' planning problem, and given the policy functions, prices, and the value functions $\{V^a_t, V^n_t\}$ are a solution to the Bellman equation (12).

Equilibrium

- 2. Distributions of wealth and income evolve according to households' policy functions.
- 3. The labor, the final goods, the bond, the capital, and the intermediate goods markets clear in every period, interest rates on bonds are set according to the central bank's Taylor rule, fiscal policies are set according to the fiscal rules, and stochastic processes evolve according to their law of motion.
- 4. Expectations are model consistent

Numerical Solution and Estimation Technique

- We solve the model by perturbation methods.
- We choose a first-order Taylor expansion around the stationary equilibrium following the method of Bayer and Luetticke (2020)
- This method replaces the value functions with linear interpolants and the distribution functions with histograms to calculate a stationary equilibrium.

Numerical Solution and Estimation Technique

- Approximating the sequential equilibrium in a linear state-space representation then boils down to the linearized solution of a non-linear difference equation:

$$\mathbb{E}_t F(x_t, X_t, x_{t+1}, X_{t+1}, \sigma\Sigma\epsilon_{t+1})$$

- where x_t is "idiosyncratic" states and controls: the value and distribution functions, and X_t is aggregate states and controls: prices, quantities, productivities, etc.

- We can also order the equations in a similar way: The law of motion for the distribution, the Bellman equations, and all other optimality and market clearing conditions for the aggregate variables.

Numerical Solution and Estimation Technique

- As this method will greatly increase the dimension of model.
- Then it performs dimensionality reduction before linearization but after calculation of the stationary equilibrium.
- The dimensionality reduction is achieved by using discrete cosine transformations (DCT) for the value functions and perturbing only the largest coefficients of this transformation.
- Approximating the joint distributions through distributions with a fixed copula and flexible marginals.

Calibration

- For the household side, we set the relative risk aversion to 4, which is common in the incomplete markets literature; see Kaplan et al. (2018).
- We set the Frisch elasticity to 0.5; see Chetty et al. (2011). We take estimates for idiosyncratic income risk from Storesletten et al. (2004), $\rho_h = 0.98$ and $\bar{\sigma}_h = 0.12$.
- Guvenen et al. (2014) provide the probability that a household will fall out of the top 1% of the income distribution in a given year, which we take as the transition probability from entrepreneur to worker, $\iota = 1/16$.

Calibration

- Some of parameters $\{\beta, \lambda, \zeta, \bar{R}\}$ are calibrated by targeting to: (1) average illiquid assets $K/Y = 11.44$; (2) average liquidity $B/Y = 1.58$; (3) the fraction of borrowers, 16%; (4) the average top 10% share of wealth, which is 67%.
- For the firm side, we set the labor share in production, α, to 68% to match a labor income share of 62%, which corresponds to the average BLS labor share measure over 1954 - 2015. The depreciation rate is 1.75% per quarter.
- An elasticity of substitution between differentiated goods of 11 yields a markup of 10%. The elasticity of substitution between labor varieties is also set to 11, yielding a wage markup of 10%.

Calibration

Table 1: External/calibrated parameters (quarterly frequency)

Parameter	Value	Description	Target
Households			
β	0.981	Discount factor	see Table 2
ξ	4	Relative risk aversion	Kaplan et al. (2018)
γ	2	Inverse of Frisch elasticity	Chetty et al. (2011)
λ	0.065	Portfolio adj. prob.	see Table 2
ρ_h	0.98	Persistence labor income	Storesletten et al. (2004)
σ_h	0.12	STD labor income	Storesletten et al. (2004)
ζ	1/5000	Trans.prob. from W. to E.	see Table 2
ι	1/16	Trans.prob. from E. to W.	Guvenen et al. (2014)
$\bar{R}$	1.65%	Borrowing penalty	see Table 2
Firms			
α	0.68	Share of labor	62% labor income
δ_0	1.75%	Depreciation rate	7.0% p.a.
$\bar{\eta}$	11	Elasticity of substitution	Price markup 10%
$\bar{\zeta}$	11	Elasticity of substitution	Wage markup 10%
Government			
$\bar{\tau}^L$	0.12	Tax rate level	$G/Y = 20\%$
$\bar{\tau}^P$	0.18	Tax progressivity	Heathcote et al. (2017)
$\bar{R}^b$	1.004	Nominal rate	1.6% p.a.
$\bar{\pi}$	1.00	Inflation	0% p.a.

Estimation Data

- We use quarterly US data from 1954Q3 to 2015Q4 and include the following eight observable time series:
- (1) the growth rates of per capita GDP; (2) private consumption, (3) investment, (4) federal tax receipts, (5) wages, (6) the logarithm of the level of per capita hours worked, (7) the log difference of the GDP deflator, (8) the (shadow) federal funds rate.

- We add more data with shorter and/or non-quarterly availability:
- (1) Idiosyncratic income uncertainty (1983Q1 to 2013Q1), (2) We proxy the progressivity of the US tax and transfer system by the highest bracket of the US individual income tax (available at annual frequency from 1954 to 2015); (3) Wealth and income shares of the top 10% (annual frequency and available from 1954 to 2014).

Estimation Data

- As the solution of HANK model can be expressed by linear state space model;
- Thus we can easily tackle with the missing observations in the data by using kalman filter.
- Also, we can estimate the deep parameters with above filter and standard RWMH (Bayesian method).
- Up to here, we are ready to answer the first question:
- (1) Does the inclusion of measures of inequality change what the model infers about shocks and frictions in business cycles?

Parameter Estimates w/ and w/o Inequality

- Strikingly, the parameter estimates with and without data on inequality are basically the same;
- None of the estimated parameters is substantially different across the two estimations.

Table 3: Prior and posterior distributions of estimated parameters

Parameter	Prior			Posterior HANK				Posterior HANK*			
	Distribution	Mean	Std. Dev.	Mean	Std. Dev.	5 %	95 %	Mean	Std. Dev.	5%	95%
Frictions											
δ_s	Gamma	5.00	2.00	1.483	0.137	1.265	1.717	1.420	0.031	1.371	1.472
ϕ	Gamma	4.00	2.00	0.233	0.032	0.182	0.288	0.218	0.036	0.162	0.278
κ	Gamma	0.10	0.02	0.101	0.014	0.080	0.126	0.105	0.014	0.083	0.129
κ_w	Gamma	0.10	0.02	0.128	0.017	0.100	0.157	0.133	0.019	0.103	0.164
Debt and monetary policy rules											
ρ_R	Beta	0.50	0.20	0.800	0.016	0.774	0.825	0.803	0.014	0.779	0.826
σ_R	Inv.-Gamma	0.10	2.00	0.265	0.015	0.241	0.291	0.266	0.016	0.242	0.293
θ_π	Normal	1.70	0.30	2.603	0.125	2.404	2.817	2.614	0.053	2.520	2.695
θ_y	Normal	0.13	0.05	0.086	0.020	0.054	0.119	0.078	0.018	0.048	0.107
γ_B	Gamma	0.10	0.08	0.144	0.018	0.116	0.174	0.157	0.021	0.119	0.190
γ_π	Normal	0.00	1.00	-1.134	0.031	-1.185	-1.083	-1.175	0.025	-1.215	-1.135
γ_Y	Normal	0.00	1.00	-0.716	0.030	-0.765	-0.668	-0.697	0.026	-0.741	-0.655
ρ_G	Beta	0.50	0.20	0.988	0.008	0.972	0.997	0.992	0.005	0.981	0.998
σ_G	Inv.-Gamma	0.10	2.00	0.260	0.015	0.237	0.286	0.263	0.016	0.238	0.289

Parameter Estimates w/ and w/o Inequality

- Strikingly, the parameter estimates with and without data on inequality are basically the same;
- None of the estimated parameters is substantially different across the two estimations.

Table 3: Prior and posterior distributions of estimated parameters - continued

Parameter		Prior		Posterior HANK				Posterior HANK*			
	Distribution	Mean	Std. Dev.	Mean	Std. Dev.	5 %	95 %	Mean	Std. Dev.	5%	95%
				Structural Shocks							
ρ_A	Beta	0.50	0.20	0.977	0.011	0.957	0.992	0.983	0.009	0.965	0.995
σ_A	Inv.-Gamma	0.10	2.00	0.160	0.014	0.139	0.184	0.159	0.013	0.140	0.181
ρ_Z	Beta	0.50	0.20	0.995	0.002	0.991	0.999	0.992	0.003	0.986	0.996
σ_Z	Inv.-Gamma	0.10	2.00	0.601	0.028	0.558	0.649	0.608	0.029	0.564	0.658
ρ_Ψ	Beta	0.50	0.20	0.976	0.008	0.963	0.988	0.965	0.009	0.950	0.978
σ_Ψ	Inv.-Gamma	0.10	2.00	2.723	0.229	2.362	3.107	2.531	0.214	2.197	2.895
ρ_μ	Beta	0.50	0.20	0.889	0.022	0.852	0.923	0.900	0.021	0.863	0.933
σ_μ	Inv.-Gamma	0.10	2.00	1.695	0.149	1.471	1.958	1.645	0.139	1.435	1.889
$\rho_{\mu w}$	Beta	0.50	0.20	0.909	0.020	0.873	0.938	0.909	0.020	0.875	0.938
$\sigma_{\mu w}$	Inv.-Gamma	0.10	2.00	5.355	0.513	4.605	6.272	5.216	0.541	4.441	6.158

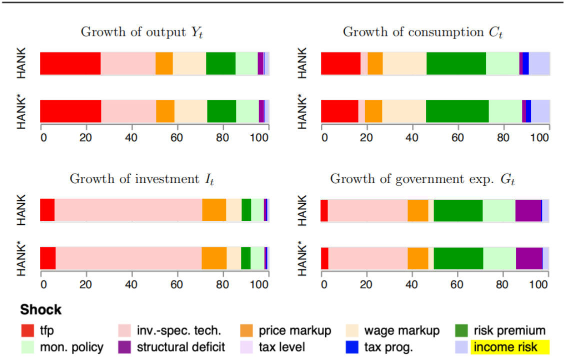
Parameter Estimates w/ and w/o Inequality

- This implies that both inequality measures provide little additional identification of business cycle shocks and frictions.
- In the next section on US inequality, we show that already the model estimated only on aggregate data implies a U-shaped evolution of inequality from 1950 to 2015 in line with the data.
- This explains why adding data on inequality has little effect on the estimated parameters.
- The estimated shocks and frictions do a good job in matching the evolution of wealth and income inequality over the last 60 years

Variance Decompositions w/ and w/o Inequality

- Unsurprisingly, we find very similar decompositions for the estimations with and without using inequality data.

Figure 1: Variance decompositions: Output growth and its components

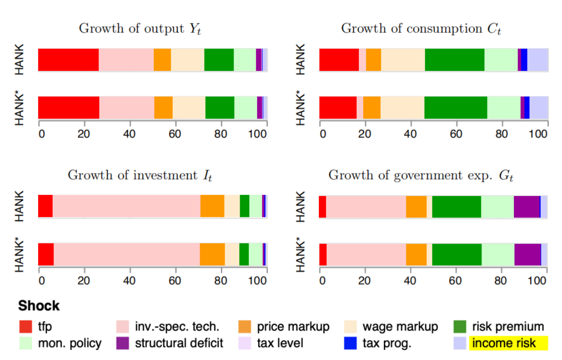


Notes: Conditional variance decompositions at a 4-quarter forecast horizon. HANK* [HANK] corresponds to the estimated HANK model with inequality data [w/o inequality data].

Variance Decompositions w/ and w/o Inequality

- As in the representative-agent literature, TFP and investment specific technology shocks are the most important drivers of output growth. All together, supply side shocks (the two markup and the two productivity shocks) account for almost 75% of output volatility.

Figure 1: Variance decompositions: Output growth and its components



Notes: Conditional variance decompositions at a 4-quarter forecast horizon. HANK* [HANK] corresponds to the estimated HANK model with inequality data [w/o inequality data].

Historical Decompositions w/ and w/o Inequality

Shocks	Output growth HANK	Output growth HANK*	Consumption growth HANK	Consumption growth HANK*
TFP, ϵ^Z	-0.23	-0.27	-0.16	-0.18
Inv.-spec. tech., ϵ^Ψ	-0.25	-0.22	0.14	0.15
Price markup, $\epsilon^{\mu Y}$	-0.03	-0.03	-0.10	-0.11
Wage markup, $\epsilon^{\mu W}$	-0.31	-0.31	-0.52	-0.50
Risk premium, ϵ^A	-0.27	-0.27	-0.39	-0.38
Monetary policy, ϵ^R	0.12	0.13	0.23	0.23
Structural deficit, ϵ^G	0.02	0.02	-0.03	-0.07
Tax level, ϵ^τ	0.00	0.00	0.00	0.00
Tax progressivity, ϵ^{τ^P}	0.01	0.01	0.00	0.00
Income risk, ϵ^σ	-0.06	-0.05	-0.18	-0.14

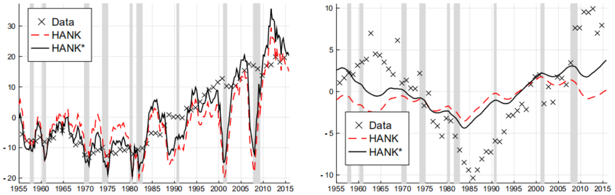
Notes: The table displays the average contribution of the various shocks during an NBER-dated recession that result from our historical shock decomposition. Values are calculated by averaging the value of each shock component over all NBER recession quarters. To improve readability, we normalized the size of the overall contraction to -1%. In the data, the average is -1.24% for output and -0.5% for consumption.

US inequality – data vs. model

- Now, we start to answer the second question:
- (2) How important are business cycle shocks for the evolution of US inequality?

US inequality – data vs. model

- Business cycle shocks can move inequality along the lines of what we observe in the data.
- This matching of the distributional data, on top of the "standard" macroeconomic time series, does not change significantly what we infer about shocks and frictions.

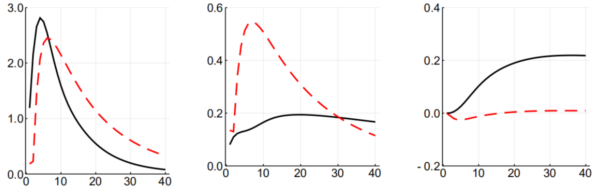


(a) Top 10% income share (b) Top 10% wealth share

Notes: Data (crosses) correspond to log-deviations of the annual observations of the share of pre-tax income and wealth held by the top 10% in each distribution in the US taken from the World Inequality Database. HANK* (solid) [HANK (dashed)] corresponds to the smoothed states of both implied by the estimated HANK model with inequality data [w/o inequality data]. Shaded areas correspond to NBER-dated recessions.

Propagation of Inequality

- Why is the model able to explain the slow-moving inequality dynamics?
- Our model implies that business cycle shocks have very persistent effects on the wealth distribution.



(a) Top 10% income share (b) Consumption Gini (c) Top 10% wealth share

Notes: Response (in percent) of the top 10% pre-tax income share, the consumption Gini, and the top 10% wealth share to a one standard deviation price-markup shock (solid, black) and income-risk shock (dashed, red). The response of the Gini coefficient/top 10% shares is calculated by including them as a generalized moment in the linearized model.

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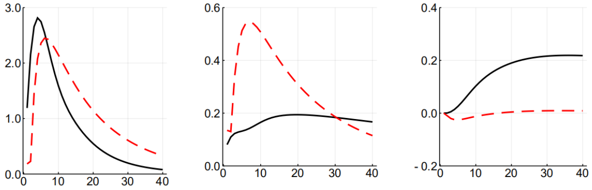

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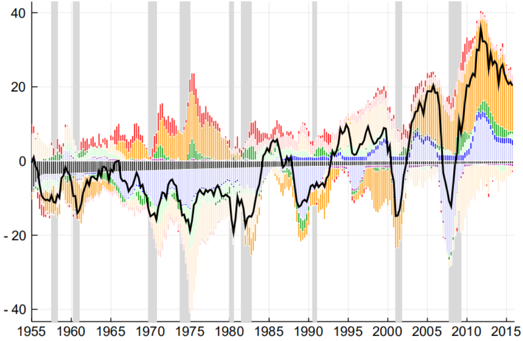
Historical decompositions of US inequality

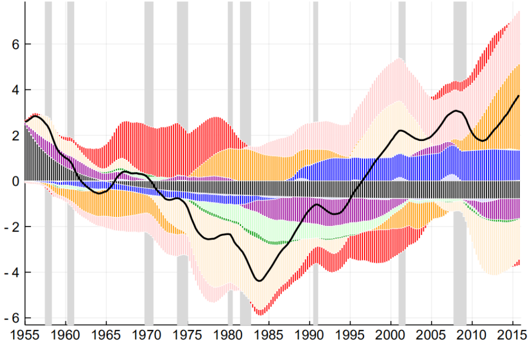
- Medium-term trends of income inequality primarily result from markup shocks and fluctuations in income risk.
- Rising wage markups and low idiosyncratic productivity risks are mainly responsible for the decrease in income inequality throughout the 1960s until the 1970s



(a) Top 10% income share

Historical decompositions of US inequality

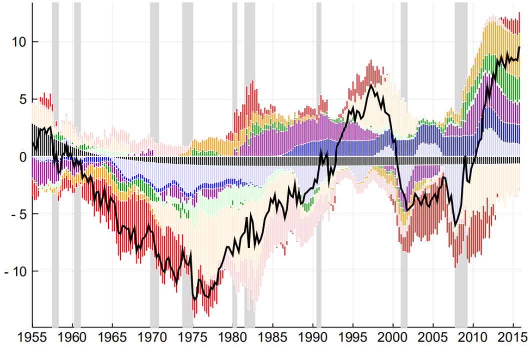
- Wage markup, investment technology, and monetary shocks are the strongest downward drivers of wealth inequality.
- From the 1980s on, it is then mainly shocks to investment technology and fiscal policy (deficits and tax progressivity).



(b) Top 10% wealth share

Historical decompositions of US inequality

- Income risk is the most important driver of short-run fluctuations in consumption inequality.
- The long-run trend in consumption inequality is primarily due to markups and fiscal policy.



(c) Gini coefficient of consumption

Contribution of shocks to US inequality

- The business cycle shocks in our model capture virtually all the observed increase in income inequality and roughly half of the increase in wealth inequality.

Shock	Top 10% Income	Top 10% Wealth	Gini Consumption
TFP, ϵ^Z	-0.30	-1.14	-0.33
Inv.-spec. tech., ϵ^Ψ	1.32	2.63	1.62
Price markup, $\epsilon^{\mu Y}$	11.99	2.44	2.50
Wage markup, $\epsilon^{\mu W}$	8.83	0.90	3.46
Risk premium, ϵ^A	-0.51	0.06	1.72
Monetary policy, ϵ^R	6.81	0.72	2.10
Structural deficit, ϵ^G	-0.84	-0.94	1.55
Tax level, τ	0.00	0.00	0.00
Tax progressivity, τ^P	2.06	1.70	2.23
Income risk, ϵ^σ	8.99	0.07	2.35
Sum of shocks	39.56	6.25	17.40

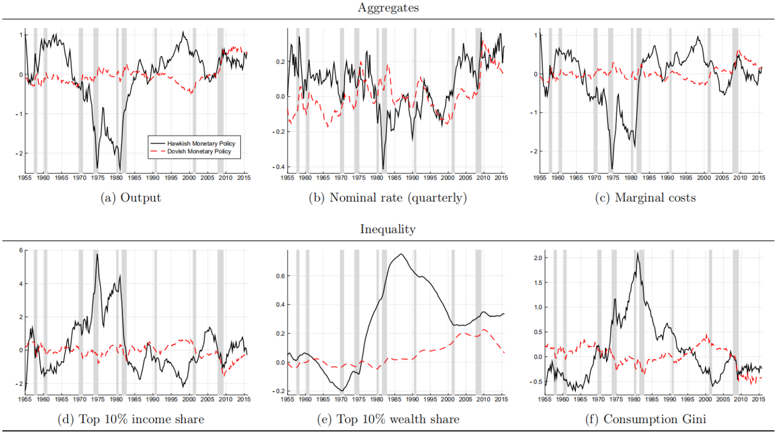
Notes: The table displays the contribution (in p.p.) of the various shocks to the increase in the top 10% share of pre-tax income, top 10% share of wealth, and the Gini coefficient of consumption from 1980 to 2015 based on our historical shock decompositions.

Inequality Counterfactuals

- Finally, we answer the third question:
- (3) How important are the estimated policy coefficients for the evolution of inequality?
- To understand the role of policies in shaping inequality, run a set of counterfactual monetary and fiscal policy experiments based on the estimated model.
- First, we consider an experiment where the Fed reacts very aggressively to inflation

Inequality Counterfactuals

- The model attributes a substantial fraction of the fluctuations of the 70s to markup (cost-push) shocks, thus the Hawkish policy would have led to higher output, and lower inequality.

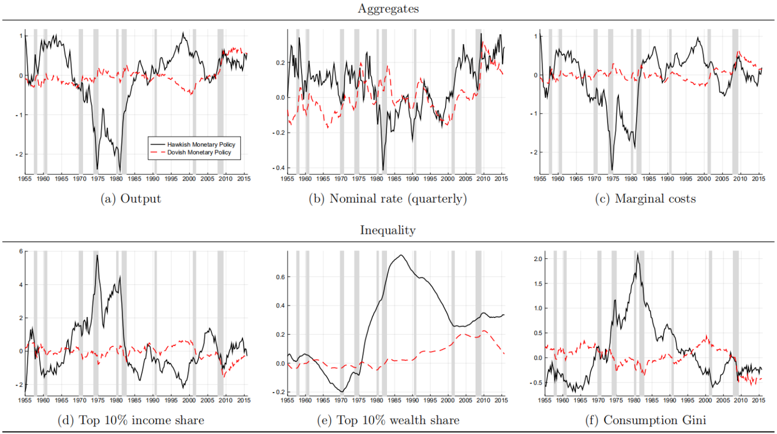


(a) Output (b) Nominal rate (quarterly) (c) Marginal costs

(d) Top 10% income share (e) Top 10% wealth share (f) Consumption Gini

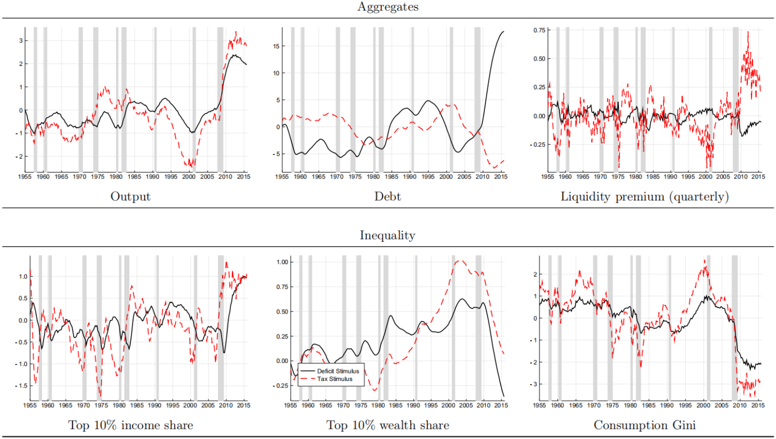
Inequality Counterfactuals

- Dovish policy leads to more stable markups and output at the expense of higher inflation volatility.



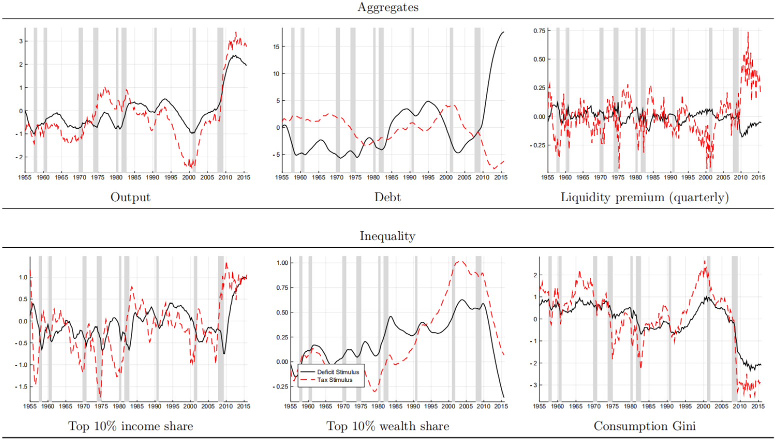
Inequality Counterfactuals

- The more active deficit scenario, government debt rises almost by another 50% and output is initially more stable after 2008.
- A substantially lower liquidity premium reduces wealth inequality, but drives up income and consumption inequality.



Inequality Counterfactuals

- Cutting taxes more aggressively during the Great Recession would have stabilized output and hence consumption inequality more strongly.
- However, this would have increased the liquidity premium, putting further downward pressure on nominal rates.



Conclusion

- This paper finds that household heterogeneity and the inclusion of micro data in the estimation do not materially alter the shocks and frictions in US business cycles.
- We show that business cycle shocks and policy responses can account for 50of the increase in US wealth inequality and virtually all of the increase in income inequality since the 1980s.
- Our analysis suggests that price markups have substantially increased over the last two decades. This has driven down output and has increased income, consumption and wealth inequality.

Conclusion

- A more expansionary fiscal policy that would have had a positive impact on interest rates and thus helped the economy to escape the effective lower bound earlier and boosted the recovery.
- The evolution of government debt would have eroded the return difference between illiquid and liquid assets, helping in particular poor households to accumulate wealth, driving down wealth inequality.

Thanks