Investment-Specific Technological Change, Taxation and Inequality in the U.S.

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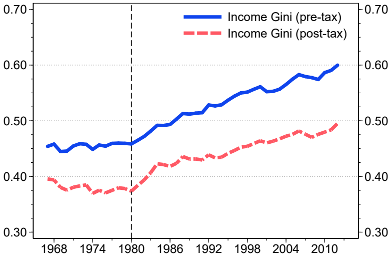
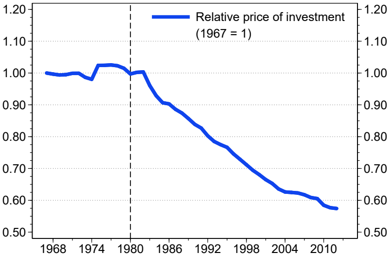
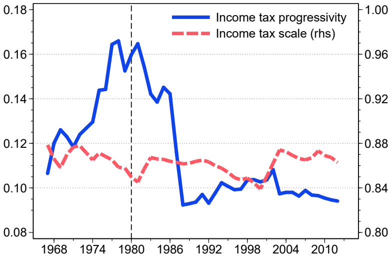
Summary

- **Question**: To what extent can the drop in investment prices and changes in taxation account for the path of income inequality?
- **Framework**: Standard incomplete markets model with a continuum of heterogeneous agents, detailed tax system, and **non-routine labor/capital complementarity**
- **Findings**:
  1. Structural changes **account for one third of the increase in the post-tax income Gini**
  2. Main mechanisms: higher non-routine wage premium and increased post-tax income dispersion
  3. Progressivity alone accounts for 16% and the investment-specific technological change alone accounts for 15%

Stylized facts - US







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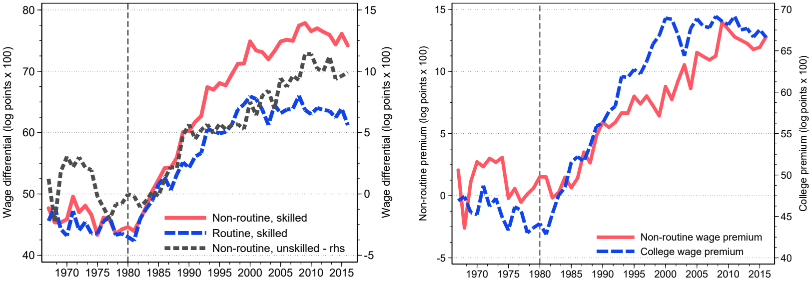


Data and regression

Model

- **Key ingredients**
  - Complementarity between capital and non-routine labor
  - Substitutability between capital and routine labor
  - Groups are calibrated to match employment. No occupational choice
  - Incomplete markets
  - Tax system and tech variables

Model

- **Production**: Karabarbounis & Neiman (2014)
  - Two sector economy: (i) final goods and (ii) intermediate goods
  - Intermediate goods sector has technology:

$$Y_t = A_t \left(\phi_1 Z_t^{\frac{\sigma-1}{\sigma}} + (1-\phi_1) {N_t}^{R,\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

$$Z_t = \left(\phi_2 (K_t)^{\frac{\rho-1}{\rho}} + (1-\phi_2) {N_t}^{NR,\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}$$

- **Taxation**: consumption, capital, SS, and labor income

$$y_a = 1 - \theta_1 y^{-\theta_2}$$

Model

- **Final goods firms**
  - Operate in perfect competition
  - Produce consumption (C and G) and investment goods (X)
  - ξ is the level of technology of investment goods firms versus consumption goods firms – higher ξ $\rightarrow$ less intermediate goods (z_t^x) required to produce the aggregate investment good

$$C_t + G_t = z_t^c$$
$$X_t = \left(\frac{1}{\xi_t}\right) z_t^x$$

  - In equilibrium, ξ equals the relative price of investment goods

Government

- Government runs a balanced social security system by taxing employers and employees, τ_{ss} and $\tilde{\tau}_{ss}$, and paying benefits, Ψ_t, to retired agents:
  - $\Psi(\sum_{j \geq 65} \Omega_j) = R^{ss}$

- Government also taxes consumption, labor and capital income to finance public consumption, G_t, interest on the national debt, $R_t B_t$, and lump sum transfers, g_t.
  - Consumption and capital income are taxed at rates τ_c, and τ_k.
  - Progressive labor income taxes.
  - Lump-sum transfers financed by government surplus:
    - $g_t \int d\Phi + G_t + R_t B_t$

Model

- **Intermediate goods firms**
  - Operate in perfect competition
  - Profit maximization:

$$r_t = \partial Y_t / \partial K_t - \delta = \left[A_t^{\sigma-1} Y_t\right]^{\frac{1}{\sigma}} \phi_1 Z_t^{\frac{\sigma-\rho}{\rho\sigma}} \phi_2 \left(\frac{1}{K_t}\right)^{\frac{1}{\rho}} - \delta$$

$$w_t^{NR} = \partial Y_t / \partial N_t^{NR} = \left[A_t^{\sigma-1} Y_t\right]^{\frac{1}{\sigma}} \phi_1 Z_t^{\frac{\sigma-\rho}{\rho\sigma}} (1-\phi_2) \left(\frac{1}{N_t^{NR}}\right)^{\frac{1}{\rho}}$$

$$w_t^{R} = \partial Y_t / \partial N_t^{R} = (1-\phi_1) \left(\frac{A_t^{\sigma-1} Y_t}{N_t^{R}}\right)^{\frac{1}{\sigma}}$$

Model

- **Demographics**
  - Households enter the labor market at 20 and retire at 65
  - Individuals assigned to group a (non-routine skilled, non-routine unskilled, routine skilled, routine unskilled), and are exposed to idiosyncratic wage risk u. w_s is the wage for the assigned labor variety (routine or non-routine)

$$
\begin{aligned}
w(j, a, u) &= w_s e^{\gamma_1 j + \gamma_2 j^2 + \gamma_3 j^3 + a + u} \\
u' &= \rho_u u + \epsilon, \quad \epsilon \sim N(0, \sigma_\epsilon^2) \\
s &= \{NR, R\}
\end{aligned}
$$

  - Accidental bequests upon death distributed lump sum to living households (Γ)
  - Retired households collect constant retirement benefit Ψ

Model

- **Household state variable**
  - Non-arbitrage condition

$$\frac{1}{\xi}\left(\xi + (r - \xi\delta)(1 - \tau_k)\right) = 1 + R(1 - \tau_k)$$

  - State variable definition

$$h \equiv [\xi + (r - \delta\xi)(1 - \tau_k)]k + (1 + R(1 - \tau_k))b$$

  - In equilibrium, by non-arbitrage:

$$h = \frac{1}{\xi}[\xi + (r - \delta\xi)(1 - \tau_k)]\,(\xi k + b)$$

Model

- **Preferences**
  - Standard additive-separable preferences in consumption and hours: $U(c, n) = \frac{c^{1-1/\lambda}}{1-1/\lambda} - \chi \frac{n^{1+1/\psi}}{1+1/\psi}$
  - Retired households gain utility from the bequest they will leave when they die: $D(h') = \varphi \log(h')$
  - Each generation consists of four types of agents with equal mass, that differ w.r.t. the time preference parameter $\beta \in \{\beta_1, \beta_2, \beta_3, \beta_4\}$

Model

- **Active household problem**

$$V(j,h,\beta,a,u) = \max_{c,n,h'} \left[U(c,n) + \beta \mathbb{E}_{u'} \left[V(j+1,h',\beta,a,u') \right] \right]$$

s.t.:

$$c(1+\tau_c) + qh' = h + \Gamma + g + Y^N$$

$$Y^N = \frac{nw(j,a,u)}{1+\tilde{\tau}_{ss}} \left(1 - \tau_{ss} - \tau_l \left(\frac{nw(j,a,u)}{1+\tilde{\tau}_{ss}} \right) \right)$$

$$n \in [0,1], \quad h' \geq -\underline{h}, \quad h_0 = 0, \quad c > 0$$

Model

- **Retired household problem**

$$V(j,h,\beta) = \max_{c,h'} \left[U\left(c,n\right) + \beta(1-\pi(j))V(j+1,h',\beta) + \pi(j)D(h') \right]$$

s.t.:

$$c(1+\tau_c) + qh' = h + \Gamma + g + \Psi$$

$$h' \geq -\underline{h}, \quad c > 0$$

Model

- **Stationary Recursive Competitive Equilibrium**
  1. $V(j, h, \beta, a, u)$, c, h', and n solve the household's optimization problem
  2. Asset markets clear:
  $$[\xi + (r - \xi\delta)(1 - \tau_k)] \left(K + \frac{1}{\xi} B \right) = \int h' + \Gamma \, d\Phi$$
  3. Labor and goods markets clear:
  $$N^{NR} = \int n \, d\Phi \qquad N^{R} = \int n \, d\Phi$$
  $$C + \xi X + G = Y$$
  4. Factor prices equal the marginal productivity of their respective factors
  5. Both the government and SS budget balance
  6. The assets of the dead are uniformly distributed among the living:
  $$\Gamma \int \omega(j) d\Phi = \int (1 - \omega(j)) \, k d\Phi.$$

Calibration

- **Preferences**: $\eta = 1$ (inverse Frisch) as in Trabandt & Uhligh (2011), $\psi = 1$ (risk-aversion)
- **Wages**: age profile of wages, $\rho_u = 0.34$, and $\sigma_\epsilon = 0.31$ are set as in Brinca et al (2016)
  - Log wage differences: $a_{NRSK} = 0.39$, $a_{NRUK} = -0.29$, $a_{RSK} = 0.10$, to match the log wage differences between groups in 1980, given the the NR wage premium (0)
  - Employment: $p_{NRSK} = 0.23$, $p_{NRUK} = 0.17$, $p_{RSK} = 0.18$, to match weight in hours worked in 1980
- **Tech**: $\sigma = 0.83$, $\rho = 5.63$, $\phi_1 = 0.52$, $\phi_2 = 0.65$. Estimation as in Eden and Gaggl (2018). Capital depreciation set to 0.06.

Production function estimation

Calibration

Table: Government and SS calibration

Parameter	Description	Value
τ_c	Consumption tax	0.050
τ_k	Capital income tax	0.469
θ_0	Tax level parameter	0.850
θ_1	Tax progressivity parameter	0.160
B/Y	Government debt	0.320
τ_{ss}	Employee SS tax	0.061
$\tilde{\tau}_{ss}$	Employer SS tax	0.061

Calibration

- **Calibration by SMM**:

$$L(\beta_1, \beta_2, \beta_3, \beta_4, \underline{h}, \chi, \varphi) = ||M_m - M_d||$$

Table: Parameters Calibrated Endogenously

Parameter	Value	Description
φ	4.28	Bequest utility
$\beta_1, \beta_2, \beta_3, \beta_4$	0.939, 0.903, 0.902, 0.890	Discount factors
χ	6.1	Disutility of work
$\underline{h}$	0.02	Borrowing limit

Calibration

Table: Calibration fit

Data moment	Data Value	Model value
65-on/all	1.51	1.51
w_{NR}/w_R	0.00	0.00
$\overline{n}$	1/3	1/3
$Q_{20}, Q_{40}, Q_{60}, Q_{80}$	$-0.01, 0.00, -0.04, 0.17$	$-0.01, 0.00, -0.04, 0.30$

Experiments

Table: Parameter shifts

Parameter	Description	1980	New SS
τ_c	Consumption tax	0.050	0.054
τ_k	Capital income tax	0.469	0.360
θ_1	Tax level parameter	0.850	0.869
θ_2	Tax progressivity parameter	0.160	0.095
B/Y	Government debt	0.320	0.880
τ_{ss}	Employee SS tax	0.061	0.077
$\tilde{\tau}_{ss}$	Employer SS tax	0.061	0.077
ξ	Investment price	1.000	0.702
p_1	NRS weight	0.226	0.392
p_2	NRU weight	0.170	0.134
p_3	RS weight	0.181	0.228

Experiments

- **Exercise**: Δ taxation & gov debt + Δ Investment price
- Model is calibrated to match new parameters of the US economy
  1. Calibrate taxes (labor, consumption, capital, SS) and debt
  2. Calibrate drop in relative investment prices (30% drop)
- **Results**:
  1. Model is able to replicate **one third of the total observed increase in the post-tax income Gini**
  2. $\uparrow$ non-routine wage premium
  3. $\downarrow$ progressivity
  4. $\uparrow$ labor supply at the top of the income distribution

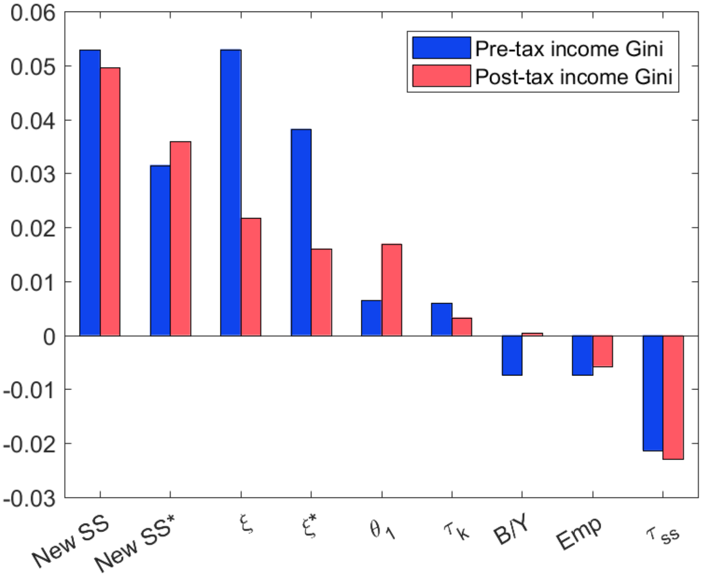
Experiments

- **Exercise**: Δ progressivity
- **Results**:
  1. 16% of the increase in the income Gini
  2. 48% of total increase predicted by the model

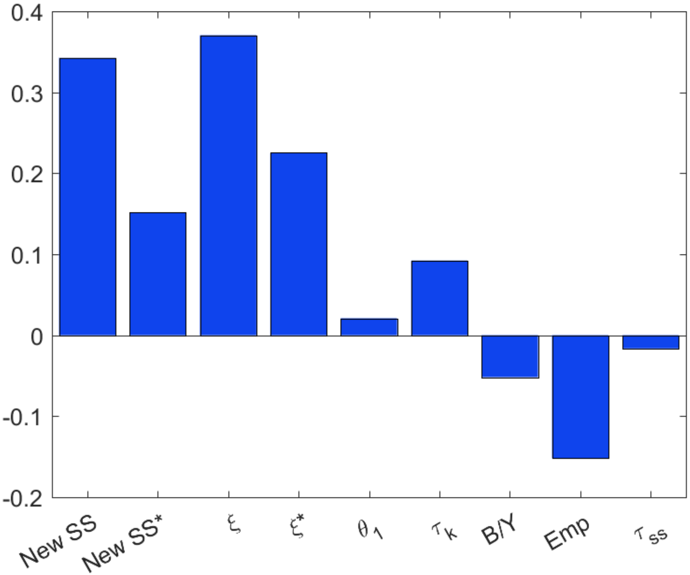
- **Exercise**: Δ IP
- **Results**:
  1. 15% of the increase in the income Gini
  2. 45% of the total increase predicted by the model

Markup model

Experiments



Experiments



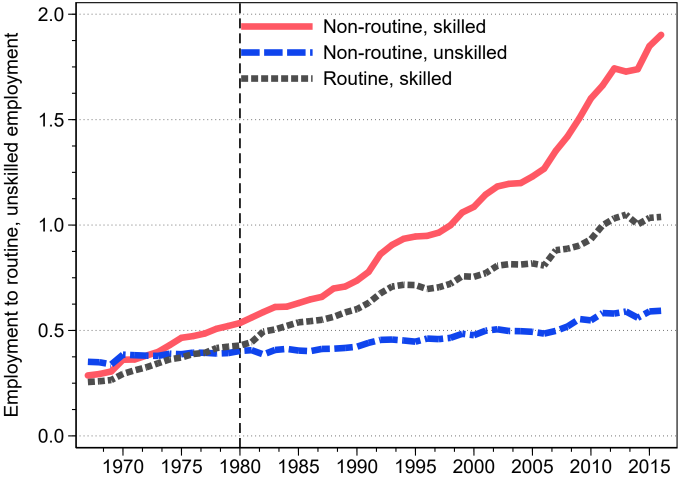
Future work

- How to model both capital/skill and capital/non-routine complementarity? What is the reason behind the co-existence of these two seemingly independent premia?
- Refine experiment: introduce BGP and model the change from 1980 to new SS as an unexpected permanent shock to the growth rate of investment specific technological change

Data

- **Source**
  - *Inequality , taxes and prices*: US Census Bureau, BEA National Account Tables and Ferriere and Navarro (2018)
  - *Employment and wages*: US Census Bureau and Bureau of Labor Statistics Current Population Survey (CPS) Annual Social and Economic Supplement (ASEC)
- **Population**: Non-military, non-institutionalized individuals aged 16 to 70, working full year, full time in the previous year, excluding those self-employed and those working in the farm sector. Note: results are unchanged if including workers not working full time or full year
- **Occupation classification**: Cortes et al (2016), based on Acemoglu and Autor (2011) "consensus classification":
  - *Non-routine*: (i) Management, Arts and Sciences; (ii) Services (nurses, policemen, cooks, hairdressers, waiters)
  - *Routine*: (i) Sales/Office; (ii) Natural resources and Construction; (iii) Production

Employment



Non-routine, skilled
Non-routine, unskilled
Routine, skilled
Employment to routine, unskilled employment
0.0
0.5
1.0
1.5
2.0
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

Wage Premium

- **Acemoglu and Autor (2011) method**
  - *Step 1*: yearly cross-sectional regression of log weekly wages on occupation type, education categories, work experience, gender, race and interactions up to the forth order between education and experience
  - *Step 2*: define gender/race/education/occupation groups and calculate the yearly weighted average wage as predicted for each group by the regression. Group weights are the average total labor supplied (hours worked) by each group across all years
  - *Step 3*: the log wage premium is defined as the difference in log wages between two groups where the only difference between those two groups is either occupation or skill

main

Production function estimation

- **Eden and Gaggl (2018) method**: factor shares imply the following system:

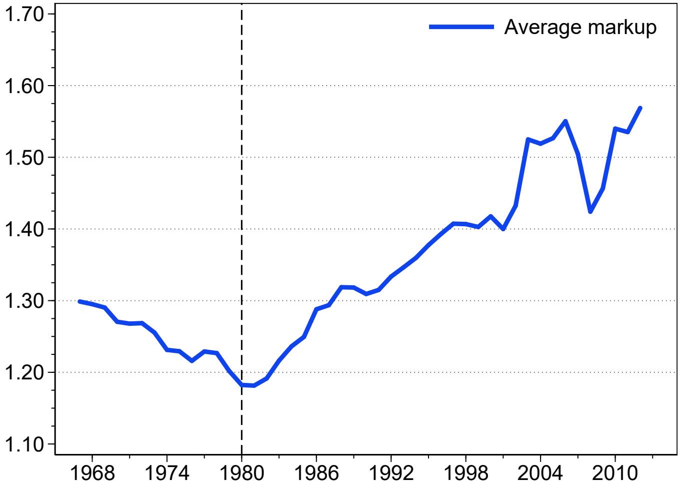
$$\ln\left(\frac{s_{K,t}}{s_{NR,t}}\right) = \ln\left(\frac{\phi_2}{1-\phi_2}\right) + \left(\frac{\rho-1}{\rho}\right)\ln\left(\frac{K_t}{N_t^{NR}}\right), \qquad (1)$$

$$\ln\left(\frac{s_{R,t}}{s_{Z,t}}\right) = \ln\left(\frac{\phi_1}{1-\phi_1}\right) + \left(\frac{\sigma-1}{\sigma}\right)\ln\left(\frac{N_t^{R}}{Z_t}\right), \qquad (2)$$

  which is estimated in two steps
- Shares for routine and non-routine labor are obtained from estimates of CPS wage data, rescaled to match the BLS non farm labor share of income. Capital is the real stock of private and public non-residential capital from the BEA fixed asset tables

back

Markup Model



Markup Model

- Final goods firms buy intermediate goods from a continuum of producers and use technology:

$$C_t + G_t = \left(\int_0^1 c_t(z)^{\frac{\epsilon_t - 1}{\epsilon_t}} dz \right)^{\frac{\epsilon_t}{\epsilon_t - 1}}$$

$$X_t = \left(\frac{1}{\xi_t} \right) \left(\int_0^1 x_t(z)^{\frac{\epsilon_t - 1}{\epsilon_t}} dz \right)^{\frac{\epsilon_t}{\epsilon_t - 1}}$$

where $c_t(z)$ and $x_t(z)$ are intermediate inputs of variety z. ϵ_t is the time varying elasticity of substitution

Markup Model

- New profit maximization conditions for intermediate goods producers:

$$\mu_t r_t = \left[A_t^{\sigma-1} Y_t\right]^{\frac{1}{\sigma}} \phi_1 Z_t^{\frac{\sigma-\rho}{\rho\sigma}} \phi_2 \left(\frac{1}{K_t}\right)^{\frac{1}{\rho}}$$

$$\mu_t w_t^{NR} = \left[A_t^{\sigma-1} Y_t\right]^{\frac{1}{\sigma}} \phi_1 Z_t^{\frac{\sigma-\rho}{\rho\sigma}} (1-\phi_2) \left(\frac{1}{N_t^{NR}}\right)^{\frac{1}{\rho}}$$

$$\mu_t w_t^{R} = (1-\phi_1) \left(\frac{A_t^{\sigma-1} Y_t}{N_t^{R}}\right)^{\frac{1}{\sigma}}$$

where $\mu_t = \frac{\epsilon_t}{\epsilon_t - 1}$ is the time-varying markup

Markup Model

- Agents can now invest in the equity of intermediate goods firms. Return on equity:

$$1 + r^e \equiv \frac{p^e + d(1 - \tau_k)}{p^e}$$

  where p^e is the price of equity and d are dividends

- New non-arbitrage condition

$$\frac{1}{\xi}(\xi + (r - \delta\xi)(1 - \tau_k)) = \frac{p^e + d(1 - \tau_k)}{p^e}$$

- New state variable of the consumer (in equilibrium)

$$h = \frac{1}{\xi}[\xi + (r - \delta\xi)(1 - \tau_k)]\,(\xi k + p^e e + b)$$

Markup Model

- Results:
  - Inequality is reduced instead of increased.
  - **Mechanism**: Profits rise $\longrightarrow$ interest rates rise by the non-arbitrage condition and capital is crowded out by the value of equity $\longrightarrow$ wages (the risky component of income) are reduced and interest income (the risk-free component of income) increases

back