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

Income Gini (pre-tax)
Income Gini (post-tax)

Relative price of investment (1967 = 1)

Income tax progressivity
Income tax scale (rhs)
Stylized facts - US
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:
    \[
    Y_t = A_t \left( \phi_1 Z_t^{\sigma-1} + (1 - \phi_1) N_t^{R, \sigma-1} \right)^{\sigma-1}
    \]
    \[
    Z_t = \left( \phi_2 (K_t)^{\rho-1} + (1 - \phi_2) N_t^{NR, \rho-1} \right)^{\rho-1}
    \]

- 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)
  - $\xi$ is the level of technology of investment goods firms versus consumption goods firms – higher $\xi \rightarrow$ less intermediate goods ($z^x_t$) required to produce the aggregate investment good

\[
C_t + G_t = z^c_t
\]
\[
X_t = \left( \frac{1}{\xi_t} \right) z^x_t
\]

- In equilibrium, $\xi$ equals the relative price of investment goods
Government

- Government runs a balanced social security system by taxing employers and employees, $\tau_{ss}$ and $\tilde{\tau}_{ss}$, and paying benefits, $\Psi_t$, 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, $R_tB_t$, and lump sum transfers, $g_t$.
  - Consumption and capital income are taxed at rates $\tau_c$, and $\tau_k$.
  - Progressive labor income taxes.
  - Lump-sum transfers financed by government surplus:
    $g_t \int d\Phi + G_t + R_tB_t$
Intermediate goods firms

- Operate in perfect competition
- Profit maximization:

\[
\begin{align*}
    r_t &= \frac{\partial Y_t}{\partial K_t} - \delta = \left[ A_t^{\sigma-1} Y_t \right] \frac{1}{\sigma} \phi_1 Z_t^{\sigma-\rho} \phi_2 \left( \frac{1}{K_t} \right)^{\frac{1}{\rho}} - \delta \\
    w_{tNR} &= \frac{\partial Y_t}{\partial N_t^{NR}} = \left[ A_t^{\sigma-1} Y_t \right] \frac{1}{\sigma} \phi_1 Z_t^{\sigma-\rho} (1 - \phi_2) \left( \frac{1}{N_t^{NR}} \right)^{\frac{1}{\rho}} \\
    w_t^R &= \frac{\partial Y_t}{\partial N_t^R} = (1 - \phi_1) \left( \frac{A_t^{\sigma-1} Y_t}{N_t^R} \right)^{\frac{1}{\sigma}}
\end{align*}
\]
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)

$$w(j, a, u) = w_s e^{\gamma_1 j + \gamma_2 j^2 + \gamma_3 j^3 + a + u}$$

$$u' = \rho_u u + \epsilon, \quad \epsilon \sim N(0, \sigma^2_\epsilon)$$

$s = \{NR, R\}$

- Accidental bequests upon death distributed lump sum to living households ($\Gamma$)

- Retired households collect constant retirement benefit $\Psi$
Model

- **Household state variable**
  - **Non-arbitrage condition**
    \[
    \frac{1}{\xi} (\xi + (r - \xi \delta)(1 - \tau_k)) = 1 + R(1 - \tau_k)
    \]
  - **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 \( \beta \in \{\beta_1, \beta_2, \beta_3, \beta_4\} \)
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.:
\[
c(1 + \tau_c) + qh' = h + \Gamma + g + Y^N
\]

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

\[ n \in [0, 1], \quad h' \geq -h, \quad h_0 = 0, \quad c > 0 \]
Model

Retired household problem

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

s.t.:
\[ c(1 + \tau_c) + qh' = h + \Gamma + g + \Psi \]
\[ h' \geq -h, \quad c > 0 \]
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:
     $$\left[\xi + (r - \xi \delta)(1 - \tau_k)\right]\left(K + \frac{1}{\xi}B\right) = \int h' + \Gamma \, d\Phi$$
  3. Labor and goods markets clear:
     $$N^{NR} = \int n \, d\Phi \quad \quad N^R = \int n \, d\Phi$$
     $$C + \xi X + G = Y$$
  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:
     $$\Gamma \int \omega(j) \, d\Phi = \int (1 - \omega(j)) \, kd\Phi.$$
Calibration

- **Preferences:** $\eta = 1$ (inverse Frisch) as in Trabandt & Uhlig (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.
## Table: Government and SS calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau_c$</td>
<td>Consumption tax</td>
<td>0.050</td>
</tr>
<tr>
<td>$\tau_k$</td>
<td>Capital income tax</td>
<td>0.469</td>
</tr>
<tr>
<td>$\theta_0$</td>
<td>Tax level parameter</td>
<td>0.850</td>
</tr>
<tr>
<td>$\theta_1$</td>
<td>Tax progressivity parameter</td>
<td>0.160</td>
</tr>
<tr>
<td>B/Y</td>
<td>Government debt</td>
<td>0.320</td>
</tr>
<tr>
<td>$\tau_{ss}$</td>
<td>Employee SS tax</td>
<td>0.061</td>
</tr>
<tr>
<td>$\tilde{\tau}_{ss}$</td>
<td>Employer SS tax</td>
<td>0.061</td>
</tr>
</tbody>
</table>
Calibration

Calibration by SMM:

\[ L(\beta_1, \beta_2, \beta_3, \beta_4, h, \chi, \varphi) = \| M_m - M_d \| \]

Table: Parameters Calibrated Endogenously

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \varphi )</td>
<td>4.28</td>
<td>Bequest utility</td>
</tr>
<tr>
<td>( \beta_1, \beta_2, \beta_3, \beta_4 )</td>
<td>0.939, 0.903, 0.902, 0.890</td>
<td>Discount factors</td>
</tr>
<tr>
<td>( \chi )</td>
<td>6.1</td>
<td>Disutility of work</td>
</tr>
<tr>
<td>( h )</td>
<td>0.02</td>
<td>Borrowing limit</td>
</tr>
</tbody>
</table>
Table: Calibration fit

<table>
<thead>
<tr>
<th>Data moment</th>
<th>Data Value</th>
<th>Model value</th>
</tr>
</thead>
<tbody>
<tr>
<td>65-on/all</td>
<td>1.51</td>
<td>1.51</td>
</tr>
<tr>
<td>$w_{NR}/w_R$</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>$\bar{n}$</td>
<td>1/3</td>
<td>1/3</td>
</tr>
<tr>
<td>$Q_{20}, Q_{40}, Q_{60}, Q_{80}$</td>
<td>$-0.01, 0.00, -0.04, 0.17$</td>
<td>$-0.01, 0.00, -0.04, 0.30$</td>
</tr>
</tbody>
</table>
## Experiments

**Table: Parameter shifts**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>1980</th>
<th>New SS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau_c$</td>
<td>Consumption tax</td>
<td>0.050</td>
<td>0.054</td>
</tr>
<tr>
<td>$\tau_k$</td>
<td>Capital income tax</td>
<td>0.469</td>
<td>0.360</td>
</tr>
<tr>
<td>$\theta_1$</td>
<td>Tax level parameter</td>
<td>0.850</td>
<td>0.869</td>
</tr>
<tr>
<td>$\theta_2$</td>
<td>Tax progressivity parameter</td>
<td>0.160</td>
<td>0.095</td>
</tr>
<tr>
<td>B/Y</td>
<td>Government debt</td>
<td>0.320</td>
<td>0.880</td>
</tr>
<tr>
<td>$\tau_{ss}$</td>
<td>Employee SS tax</td>
<td>0.061</td>
<td>0.077</td>
</tr>
<tr>
<td>$\tilde{\tau}_{ss}$</td>
<td>Employer SS tax</td>
<td>0.061</td>
<td>0.077</td>
</tr>
<tr>
<td>$\xi$</td>
<td>Investment price</td>
<td>1.000</td>
<td>0.702</td>
</tr>
<tr>
<td>$p_1$</td>
<td>NRS weight</td>
<td>0.226</td>
<td>0.392</td>
</tr>
<tr>
<td>$p_2$</td>
<td>NRU weight</td>
<td>0.170</td>
<td>0.134</td>
</tr>
<tr>
<td>$p_3$</td>
<td>RS weight</td>
<td>0.181</td>
<td>0.228</td>
</tr>
</tbody>
</table>
Experiments

- **Exercise**: $\Delta$ taxation & gov debt + $\Delta$ 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**: $\Delta$ progressivity
- **Results**:
  1. 16% of the increase in the income Gini
  2. 48% of total increase predicted by the model

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

- **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

  - *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

![Graph showing employment trends]

- Non-routine, skilled
- Non-routine, unskilled
- Routine, skilled

Time periods: 1970 to 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
Production function estimation

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

\[
\begin{align*}
\ln \left( \frac{SK}{SNR} \right)_t &= \ln \left( \frac{\phi_2}{1 - \phi_2} \right) + \left( \frac{\rho - 1}{\rho} \right) \ln \left( \frac{K_t}{N_{NR}^t} \right), \\
\ln \left( \frac{SR}{SZ} \right)_t &= \ln \left( \frac{\phi_1}{1 - \phi_1} \right) + \left( \frac{\sigma - 1}{\sigma} \right) \ln \left( \frac{N_R^t}{Z_t} \right),
\end{align*}
\]

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
Markup Model

Average markup over time from 1968 to 2010.
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 \( z \). \( \epsilon_t \) 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
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)

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

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