Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis
Krussel, Ohanian, Ros-Rull & Violante (Econometrica, 2000)

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Introduction

- **Fact 1**: Quantity of skill of skilled labor relative to unskilled labor has increase considerably.

- **Fact 2**: The skill premium has grown significantly since 1980.

- **Question**: Why has the skill premium rise during a period of growth in the supply of skilled worker?
Introduction

- Most of the literature could not answer this question based on observables.

- They conclude that there is a implicitly latent skill-biased technological change.

- **This paper:** Focus on capital-skill complementarity.

- The stock of equipment has been growing at twice the rate of either capital structure or consumption over the postwar period (6.2% through 1975 and 7.5% after).

- Growth in the stock of equipment $\implies$ ↑ marginal product of skilled labor and ↓ the marginal product of unskilled labor.
Introduction

Results

• They estimate a four factor aggregate production function allowing for different elasticities of substitutions among the factors.

• The key substitution elasticities are consistent with capital-skill complementarity and similar to microeconomics estimates.

• Changes in observed inputs account for most of the variation in the skill premium.

• The production function is also consistent with the behavior of income shares and returns on capital over time.
Figure 1. Two measures of changes in capital equipment prices: Gordon's vs. The NIPA's (%).

Figure 2. The labor input ratio: Skilled vs. unskilled hours worked (normalized with 1963=1).

Figure 3. The skill premium: Skilled vs. unskilled wages per hour (normalized with 1963=1).

Figure 4. Labor's share of aggregate income (%).
Model

- Three final goods: \( c_t, x_{st} \) and \( x_{et} \).

- Total resources: \( y_t = c_t + x_{st} + \frac{x_{et}}{q_t} = A_t G(k_{st}, k_{et}, u_t, s_t) \)

- The production function is a Cobb-Douglas over \( k_{st} \) and a CES function of the other three inputs:

\[
G(k_{st}, k_{et}, u_t, s_t) = k_{st}^{\alpha} \left[ \mu u_t^\sigma + (1 - \mu) (\lambda k_{et}^\rho + (1 - \lambda) s_t^\rho) \right]^{(1-\alpha)/\sigma}
\]

(1)

- Complementarity requires: \( \sigma > \rho \).

- Labor is measured in efficient units: \( s_t \equiv \psi_{st} h_{st} \) and \( u_t \equiv \psi_{ut} h_{ut} \).
Model

- The Skill Premium from the model:

\[
\pi_t = \frac{(1 - \mu)(1 - \lambda)}{\mu} \left[ \lambda \left( \frac{k_{et}}{s_t} \right) + (1 - \lambda) \right]^{(\sigma - \rho)/\rho} \left( \frac{h_{ut}}{h_{st}} \right)^{1-\sigma} \left( \frac{\psi_{st}}{\psi_{ut}} \right)^{\sigma}
\]  

(2)

- Hence, the growth rate:

\[
g_{\pi_t} \simeq (1 - \sigma)(g_{h_{ut}} - g_{h_{st}}) + \sigma(g_{\psi_{st}} - g_{\psi_{ut}}) + \lambda(\sigma - \rho) \left( \frac{k_{et}}{s_t} \right)^{\rho} (g_{k_{et}} - g_{h_{st}} - g_{\psi_{st}})
\]

(3)

- Since \( \sigma < 1 \) \( \Rightarrow \) First term represents the relative quantity effect.
- Second term: the relative efficiency effect.
- Third term: the complementarity effect \( \Rightarrow \) if \( \sigma > \rho \), faster growth in equipment increases the skill premium!
Quantitative Analysis

- The model has two stochastic components:
  - The relative price of equipment.
  - The pair of efficiency factors of the two types of labor:
    \[ \ln(\psi_t) \equiv \varphi_t = \varphi_0 + \omega_t. \]

- Specification of the estimated equations:
  \[
  \frac{w_{st}h_{st} + w_{ut}h_{ut}}{Y_t} = lsh_t(\varphi_t, X_t; \phi)
  \]
  \[
  \frac{w_{st}h_{st}}{w_{ut}h_{ut}} = wbr_t(\varphi_t, X_t; \phi)
  \]
  \[
  (1 - \delta_s) + A_{t+1}G_{ks}(\varphi_{t+1}, X_{t+1}; \Phi) = E_t \left( \frac{q_t}{q_{t+1}} \right) (1 - \delta_e) + q_t A_{t+1} G_{ke}(\varphi_{t+1}, X_{t+1}; \Phi)
  \]

- Where \( X_t = \{k_{st}, k_{et}, u_t, s_t\} \), \( \phi \) contains the parameters and let \( \varepsilon_t \) be the forecast error of the expectation.
Quantitative Analysis

• Given the latent nature of $\varphi_t$ and the nonlinearity of the three equations ⇒ Estimate using simulated pseudo-maximum likelihood (SPML).

• Since the model is highly parametrized and the sample size is small (30) ⇒ Calibrate and restrict some parameters.

• Calibrate: $\delta_s, \delta_u, \eta_\varepsilon$ and $\varphi_s0$

• Estimate: $\sigma, \rho, \alpha, \lambda, \mu, \eta_\omega$ and $\varphi_u0$
Results

**Two-Step SPML Parameter Estimates, Benchmark Model**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\sigma$</th>
<th>$\rho$</th>
<th>$\alpha$</th>
<th>$\eta^2_{\omega}$</th>
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<tbody>
<tr>
<td>Value</td>
<td>.401</td>
<td>-.495</td>
<td>.117</td>
<td>.043</td>
</tr>
<tr>
<td>(Std. error)</td>
<td>(.234)</td>
<td>(.048)</td>
<td>(.007)</td>
<td>(.003)</td>
</tr>
</tbody>
</table>

**Estimated Substitution Elasticities, Benchmark Model**

Between Labor and Equipment:
- Unskilled \((1/(1 - \sigma))\) \(1.67\)
- Skilled \((1/(1 - \rho))\) \(.67\)
Results

- The estimates are consistent with the capital-skill complementarity: \( \sigma > \rho \).

- The elasticity of substitution are also consistent with the estimates of the micro literature.

- The share of income of capital structures \( \alpha \) is also very close to other studies.

- Robust to other model specifications and measurement of skill, capital structure and equipment.
Results

Performance of the Model

Figure 5. Ex post rates of return on capital equipment and structures (%).

Figure 6. Labor's share of aggregate income (%).

Figure 7. The wage-bill ratio: Skilled vs. unskilled total wages (normalized with 1963=1).

Figure 8. The skill premium: Skilled vs. unskilled wages per hour (normalized with 1963=1).
• Use the model to perform three counterfactual experiments.

• **1st experiment:** Shut down the capital skill complementarity ⇒ skill premium ↓ 40%.

• **2nd experiment:** Shut down the relative quantity effect ⇒ skill premium ↑ 60%.

• **3rd experiment:** Maintain the growth of equipment at 6.2% after 1975 ⇒ skill premium would have increased 18% less.
Results

Counterfactuals

**Figure 9.** The relative quantity effect.

**Figure 10.** The capital-skill complementarity effect.

**Figures 9–10.**—A decomposition of the benchmark model’s skill premium, 1963–91 (logs).
Results

Counterfactuals

Figure 11. — A counterfactual experiment: What capital equipment growth has contributed to the skill premium, 1963–91.
Conclusion

- This paper estimates the elasticities of substitution of a four-factor production function.

- Capital-skill complementarity provides an explanation of the 20% increase of the skill premium over 1963-1993.

- The model is also consistent with labor shares, wage bills and capital return.

- What the literature have considered as *skill-biased technological change* can be interpreted as capital-skill complementarity.
Thank you!