Robots, Growth, and Inequality: Should We Fear the Robot Revolution? The Correct Answer is "Yes"

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A Second Industrial Revolution?

- AI, machine learning, robotics, networks, sensors, big data, quantum leaps in pattern recognition (Brynjolfsson and McAfee, 2014; Ford, 2015).

- Might this combination of new technologies conquer Moravec's paradox?

Competing Narratives

- Pessimists: "Workers will become serfs working on behalf of robots' overlords in a new form of economic feudalism" (Freeman, 2015).

  Prime-age employment rate for American males will drop below 25% by 2050 (Summers, 2016).

- Optimists: We've seen this before. Historically, technological progress has created more jobs than it has destroyed.

  "Focusing only on what is lost misses a central economic mechanism by which automation affects the demand for labor: raising the value of the tasks that workers supply uniquely" (Autor, 2014).

This Paper

Builds models featuring:

- Saving done only by capitalists and skilled labor.
- Robot capital and traditional capital.
- Multi-level CES production functions with different elasticities of between different types of capital and different types of labor.

General Strategy:

- Examine a variety of models with different views about how automation will transform the labor market.

Key Results

- Automation is always very good for growth and very bad for equality.
  - Arguments for technological optimism don't work.
- Long-run impact on the real wage for low-skill labor depends on the structure of the model.
  - But the transition path is always difficult.

Model 1: Robots Do Everything

- $Q = F[K, V(L, bZ)]$
- $\sigma_2 =$ elasticity of substitution between Z and L.
- $\sigma_1 =$ elasticity of substitution between K and V.
- Adjustment costs to changing K and Z.
- Gradual increases in b.
- Flexible wage with inelastic labor supply.
- All saving and investment done by capitalists. Workers live check to check.

Short-Run Outcome

- Real wage decreases iff

$$\sigma_2 > \frac{\sigma_1}{\theta_K}$$

- Intuition:
  - $\sigma_2 = \sigma_1$ is a non-nested CES production function in which bZ and L are gross complements. So $\sigma_2 > \sigma_1$ required.
  - $\theta_k \to 0$ reduces to a 2-input CES production function where, again, bZ and L are gross complements. So the borderline value of σ_2 varies inversely with θ_k.

Long-Run Outcome

- K, GDP, Z, and w all increase:

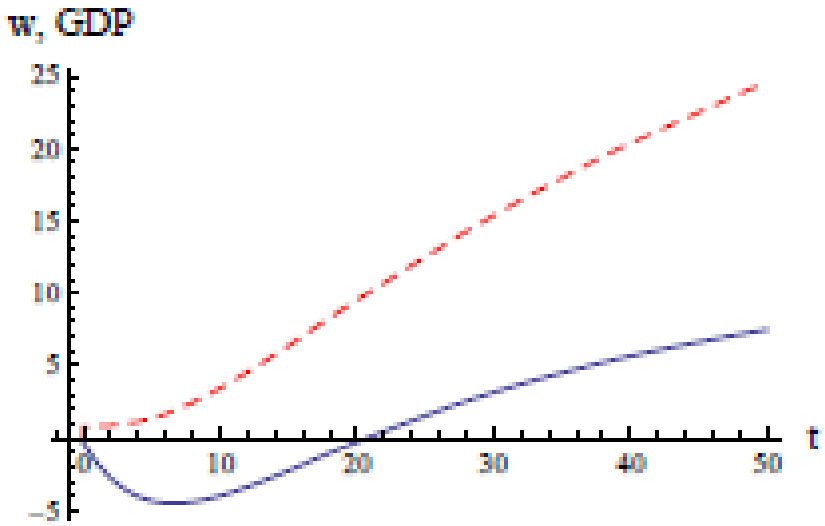
$$\begin{aligned} 1 &= C(r_k, w, r_z/b) \\ \Longrightarrow 1 &= C\left(\rho + \delta, w, \frac{\rho + \delta}{b}\right) \end{aligned}$$

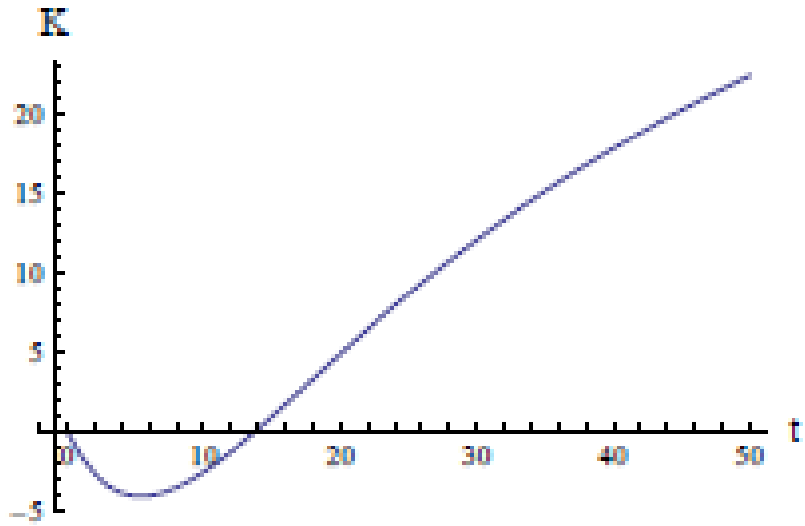
- Inequality worsens: θ_L decreases for $\sigma_2 > 1$.

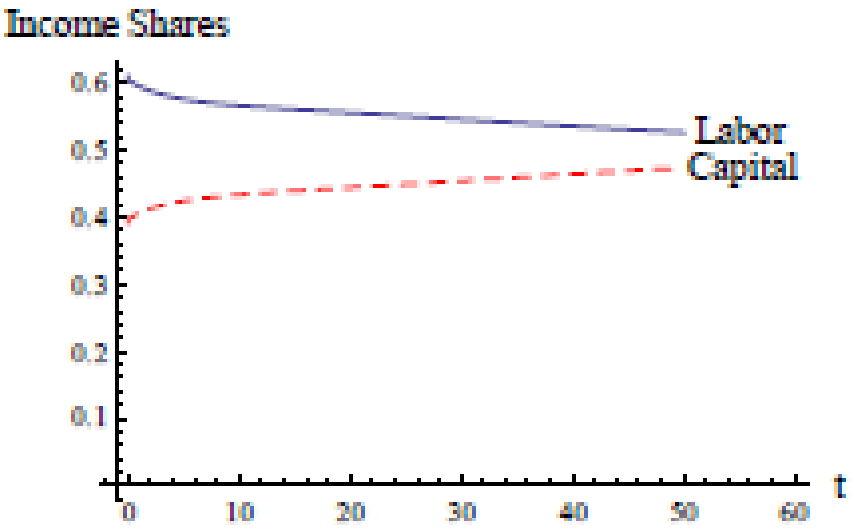
- K, GDP, Z, and w increase with σ_2, while θ_L decreases.
  - Difficult intertemporal tradeoff for labor: More short-run pain $\longrightarrow$ greater long-run gain.

Model 1: Transition Path

$\sigma_1 = .5, \sigma_2 = 2.5$, and b increases from .5 to 1.5.







Model 2: Robots Cannot Do Everything

. . . journalists and even expert commentators tend to overstate the extent of machine substitution for human labor and ignore the strong complementarities between automation and labor that increase productivity, raise earnings, and augment the demand for labor . . . Focusing only on what is lost misses a central economic mechanism by which automation affects the demand for labor: raising the value of the tasks that workers supply uniquely (Autor, 2014).

Model 2: Robots Cannot Do Everything

- $Q = F[H(K, L_2), V(L_1, bZ)]$
- $\sigma_3 =$ elasticity of substitution between K and L_2.
- L_1 and L_2 earn the same w.
- At first glance, Model 2 strengthens the case for optimism:
  - $bZ \uparrow$ reduces MPL_1, but increases MPL_2.
- On closer inspection, the argument is shaky and does not work as advertised:
  - A lot depends on σ_3.

The Bottom Line: No Grounds for Optimism

- The condition for w to decrease in the short run is weaker than in Model 1 if

$$\sigma_3 < \frac{\sigma_1}{\theta_V + \theta_H/\alpha_L} \approx \frac{\sigma_1}{1.1}$$

- Automation increases w only if σ_3 is implausibly large.

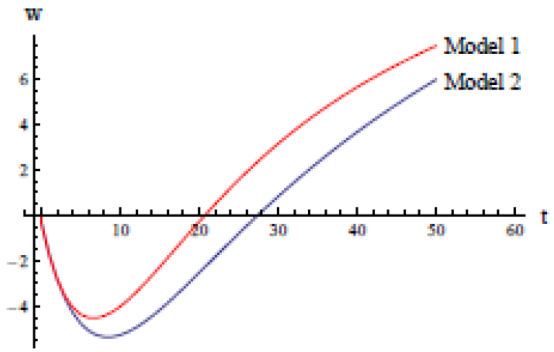
- Moreover, in the long run, w and GDP increase lessa than in Model 1 in the neutral benchmark case $\sigma_3 = \sigma_1$.

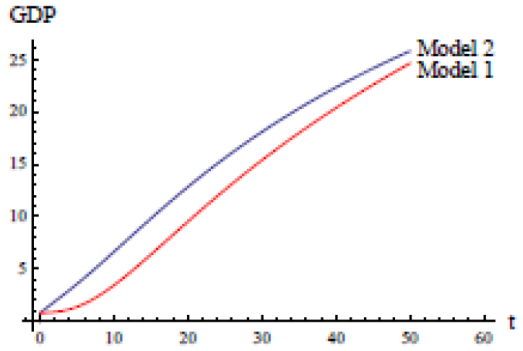
Values of σ_3^* that imply rising wages in the short run

	$\sigma_1 = .5$			$\sigma_1 = 1$		
	$\sigma_2 = 2.5$	$\sigma_2 = 5$	$\sigma_2 = 10$	$\sigma_2 = 2.5$	$\sigma_2 = 5$	$\sigma_2 = 10$
$L_2/L_1 = .5$	1.44	3.70	8.23	NA	2.89	7.41
$L_2/L_1 = 1$	1.20	2.93	6.39	NA	2.40	5.87
$L_2/L_1 = 2$	1.04	2.46	5.29	NA	2.08	4.92

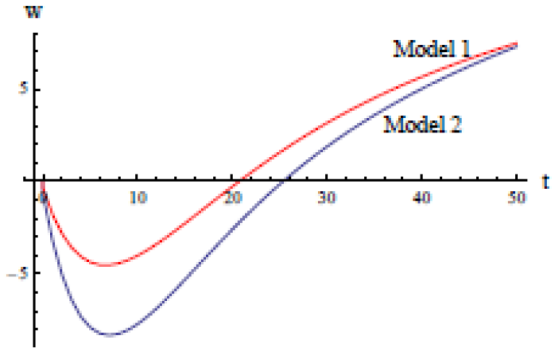
Model 1 vs Model 2 for various values of σ_3

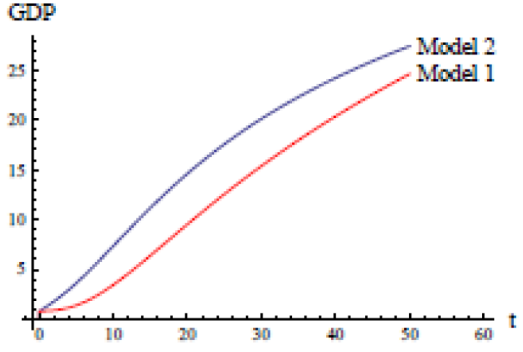
$\sigma_3 = .5$



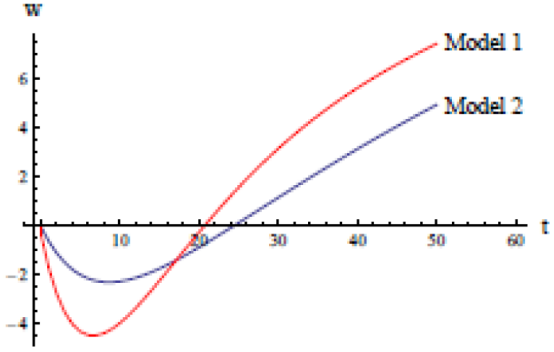


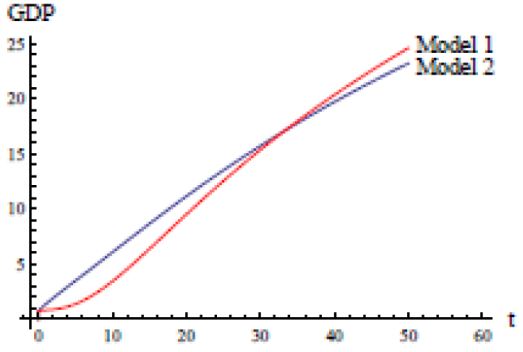
$\sigma_3 = .25$





$\sigma_3 = 1$





Model 3: Robots Do Not Substitute for Skilled Labor

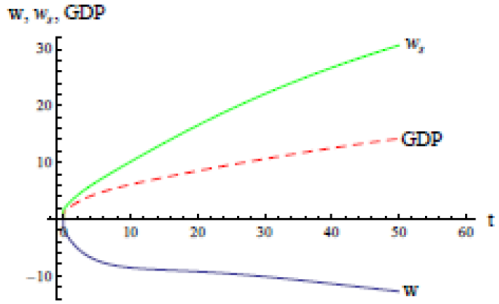
- $Q = F[H(K, S), V(L, bZ)]$
- $\sigma_3 =$ elasticity of substitution between K and skilled labor S.
- Skilled labor does great. Low-skill labor gets pummeled:
  - w_s increases in the short run and the long run.
  - w decreases in the short run iff

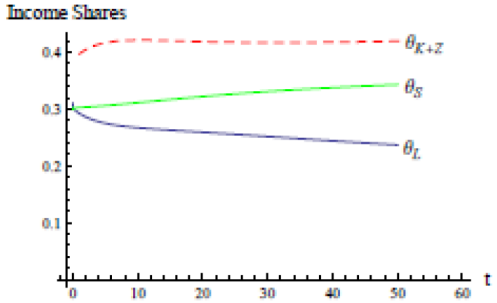
$$\sigma_2 > \frac{\sigma_1}{\theta_K + \theta_S}$$

  - No longer any guarantee that non-robot capital accumulation will increase w in the long run:
    - The weighted average wage rises, but w decreases when $\sigma_2 > 1 - 2.1$.

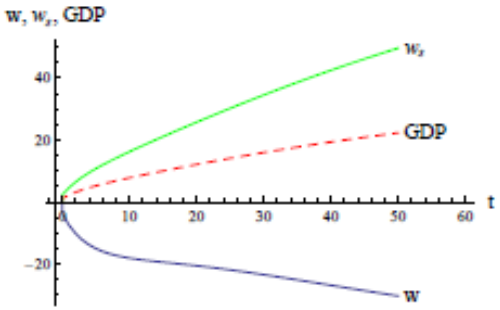
The Transition Path for various values of σ_i

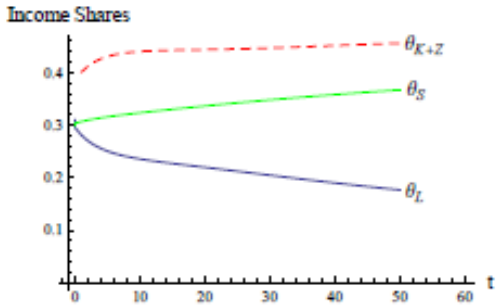
$$\sigma_2 = 2.5, \sigma_1 = .67, \sigma_3 = .33$$



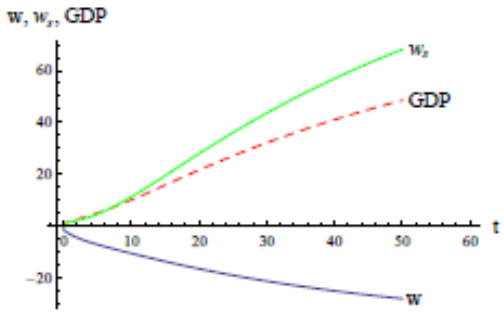


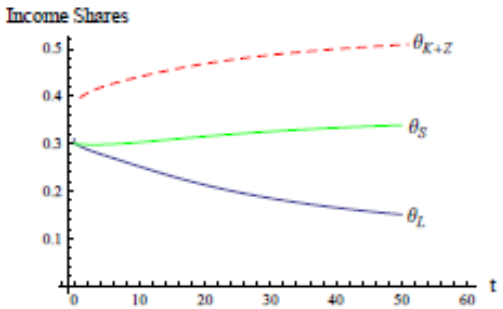
$$\sigma_2 = 5, \sigma_1 = \sigma_3 = .5$$





$$\sigma_2 = 5, \sigma_1 = 1, \sigma_3 = .5$$





Model 4: Model 3 Plus a Non-Automatable Sector

- Same production function as in the automatable sector, but no robots.
- Hope that general equilibrium interactions will generate strong growth in the demand for low-skill labor in the NA sector.
- Hard to make the story work. In the long run:

$$\hat{\omega} = \frac{[\theta_S^1(1-\gamma\theta_L^2) + \gamma\theta_S^2\theta_L^1]\hat{p}_2 - \theta_S^2\theta_Z\hat{b}}{\Delta}$$

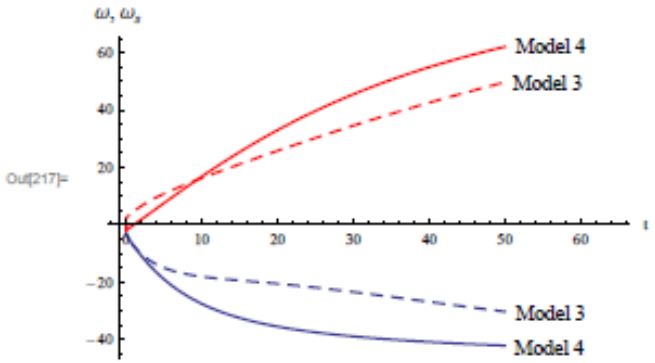
where

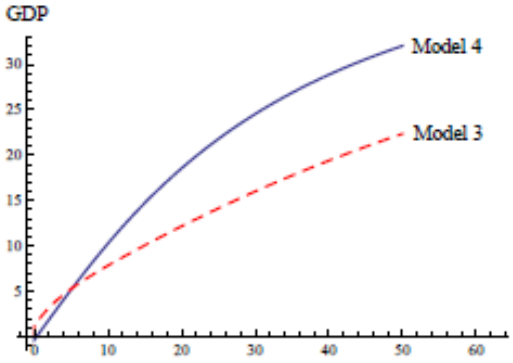
$$\Delta = \theta_S^1\theta_L^2 - \theta_S^2\theta_L^1 \quad \text{sgn} \quad L_2/S_2 - L_1/S_1$$

  - Suppose the NA sector is relatively low-skill labor intensive ($\Delta > 0$): $b\uparrow \longrightarrow \omega\downarrow$ vs. $p_2\uparrow \longrightarrow \omega\uparrow$.
  - But $p_2\uparrow$ is unlikely. Demand for the NA good increases, but massive layoffs of low-skill labor in sector 1 lead to a large rightward shift of the supply curve.

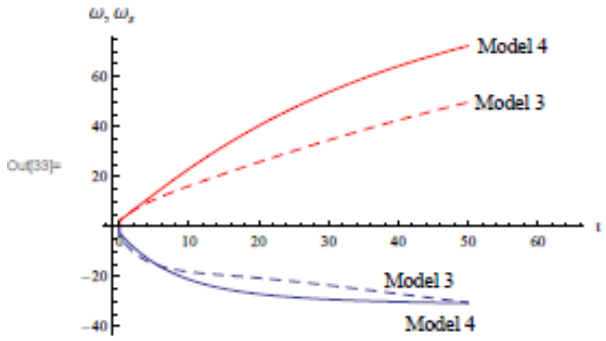
The Transition Path in the NA sector

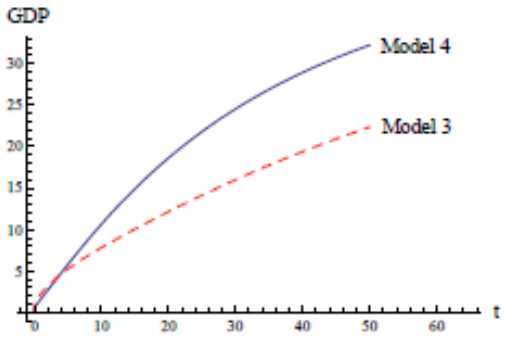
The ratio of unskilled to skilled labor in the NA sector is 1.6





The ratio of unskilled to skilled labor in the NA sector is .44





Extensions: Analysis of Potential Policy Solutions

- Invest more in education to increase the supply of skilled labor?
  - Big hill to climb in Model 3.
- Temporary tax on capital to finance the purchase of ownership shares for low-skill labor?
  - Get the same long-run results.
  - Impact on the transition path? Shuts down growth for a long time?
- Universal Basic Income?
  - Financed how?

Extensions

- International/development dimensions