Robot Arithmetic: Can New Technology Harm All Workers or the Average Worker?

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Motivation

- Recent literature on (future) labor market effects of Robotics/AI predicts strongly negative impact
  - Examples: Brynjolfson and McAfee (2014), Frey and Osborne (2017)
- Underlying economic model often not made explicit
- 'Labor immiseration' view also popular outside of economics
  - E.g. Bostrom (2014) and public press (numerous)
- Generally, most attention on direct (substitution) effects

Aim

- Restate wage and employment implications of technological change in standard economic theory
- Focus in particular on GE effects
- Make the underlying model assumptions of immiseration literature explicit

Benchmark model – environment

- finite number of types of labor, denoted by vector L
- (for now) labor supply of each type is assumed fixed
- labor is paid wage rates w
- workers supply labor for any non-zero wage
- finite number of goods, used for consumption, intermediate production (price vector p), investment (p^k)
- production technology represented as cost function, with efficiency parameter θ
- finite number of goods not restrictive: might include some with $c(\theta) = \infty$.

Benchmark model – environment (2)

Assumption *(CRS): The production function has constant returns to scale.*

- Given CRS, can define unit cost functions as $c(w, p, p^k, \theta)$ (consumption) and $c^i(w, p, p^k, \theta)$ (investment)
- Technological progress: $c_\theta \equiv \frac{\partial c(w,p,p^k,\theta)}{\partial \theta} \leq 0$ and $c^i_\theta \equiv \frac{\partial c^i(w,p,p^k,\theta)}{\partial \theta} \leq 0$, strict for at least one good
- Next: compare steady-states in this environment for different levels of technology θ
- Static labor demand (by Shepard's lemma) marginal cost times level of output:

$$L^d = X \frac{\partial c(w, p, p^k, \theta)}{\partial w} + I \frac{\partial c^i(w, p, p^k, \theta)}{\partial w} = X c_w + I c^i_w$$

- immediate analysis suggests: $\frac{\partial L^d}{\partial \theta} \lesseqgtr 0$ since $\frac{\partial^2 c}{\partial \theta \partial w} \lesseqgtr 0$
- Next: conditions under which this is unambiguously positive

Benchmark model – assumptions

Assumption *(RK): There are financial assets paying an interest rate r, which is assumed constant (for now)*

- With constant depreciation rate δ this implies $p^k = (r + \delta)p^i$ by no arbitrage.

Assumption *(PC): Input and output markets are assumed to be perfectly competitive*

- prices must be equal to unit costs.

Assumption *(HOM): Consumers' preferences are homothetic, so there is a unique consumer price index, denoted by $e(p)$.*

- Differential impact of technology on workers exclusively through wages, not prices.

Benchmark model – Results

Result 1: *Improvements in technology raise the average real wage of workers if the price index of investment goods does not increase relative to the price of consumption goods.*

- Intuition: How is the additional output distributed?
  - If relative price of investment falls, returns to *existing* capital fall, meaning that returns to labor have to increase
  - No statement on factor shares, since capital stock might adjust.
- Corollary: if there is only one type of good (consumption $+$ investment), workers gain.
- No statement on distributional consequences but about averages.

Result 2: *Improvements in technology must raise wages of at least one type of worker.*

- If there is only one type of worker, this type's real wages must rise.

Benchmark model – Results with elastic labor supply

- So far, labor assumed perfectly inelastic.
- In long run, with free occupational choice, not plausible.
- Historical evidence: shifts in labor supply much stronger than in relative wages.
- Assume now instead: perfectly elastic labor supply.

Result 3: *If labor of different types is in perfectly elastic supply, then workers of all types must gain from technological progress.*

- Perfectly elastic labor supply implies constant relative wages, implying technology must affect all wages in the same way.
- Effectively reduces model to one with single type of labor.

Role of Assumptions

1. Decreasing returns to scale
   - $\frac{\partial wL}{\partial \theta}$ can no longer be signed.
   - Plausibility? Missing fixed factor, e.g. rare earths might justify this (different narrative from existing literature).
2. Imperfect competition
   - Results fail for *changing* markups induced by technology.
   - Indirect rather than direct effect of technology on wages.
3. Rising interest rate
   - $r \uparrow$ increases returns to capital plus potentially fall in wages.
   - Why should this happen?

Role of Assumptions – 4. Non-steady states

- Static framework buys generality but inhibits transition analysis.
- Unsuited to study 'singularity', if defined as machines (robots) that are perfect (or superior) substitutes for human labor.
- Equivalent to removing labor as a fixed factor of production.
- In equilibrium under *(PC)*, wages and prices would fall to zero.
- Study of transition dynamics necessary!

Final remarks

Summary

- Formalize the discussion on labor impact of new technologies.
- Show that standard economic assumptions imply labor cannot be exclusively negatively affected.
- Identify changes in assumptions that can overturn this result.

Comments

- Static model imposes minimum assumptions on *how exactly* technology affects production.
- Excluding extreme immiseration scenarios does not mean that societal impact must not be severe (19th $\rightarrow$ 20th century, WW I etc.)
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Literature

[1] [[1]]David Autor, David Dorn, Lawrence F Katz, Christina Patterson, John Van Reenen, et al. The fall of the labor share and the rise of superstar firms. Technical report, Centre for Economic Performance, LSE, 2017.

[2] [[2]]Nick Bostrom. *Superintelligence: Paths, dangers, strategies*. OUP Oxford, 2014.

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[5] [[5]]Jan De Loecker and Jan Eeckhout. The rise of market power. 2017.

[6] [[6]]Carl Benedikt Frey and Michael A Osborne. The future of employment: how susceptible are jobs to computerisation? *Technological Forecasting and Social Change*, 114:254–280, 2017.