Robots, Trade, and Luddism

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April 3, 2020

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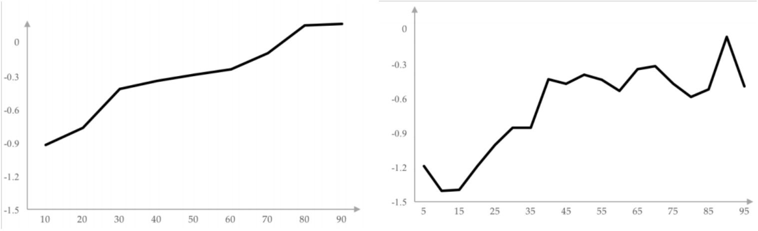
Motivation

- Empirical evidence of substantial distributional consequences of trade and technological change
  - Trade: Autor, Dorn, and Hanson (2013)
  - Robots: Acemoglu and Restrepo (2017)



(a) Robots (Acemoglu and Restrepo, 2017b) **(b)** Chinese Imports (Chetverikov, Larsen and Palmer, 2016)

Figure 1: Semi-Elasticity of wages, $\frac{d \ln w(z)}{dy_m} \times 100$, across quantiles of US wage distribution.

Research Questions

- Distributional consequences of trade and technological change lead to an equity/efficiency trade-off

- What are the implications of estimates like these for optimal policy? In particular...

  - Under what conditions is technological change welcome?

  - How should government policy respond to new technology or trade?

Summary of Results

1. Technological change / increased trade are welcome as long as they expand the aggregate production set
   - Just like in the first-best world
   - Implies no taxation of innovation
2. Optimal tax formulas that depend on sufficient statistics
   - Map empirical estimates of distributional effects onto optimal taxes
   - Tariffs and taxes on robots may be optimal as a means to "predistribute", even when nonlinear income tax is available
3. Optimal taxes on robots / tariffs may be decreasing in number of robots / amount of trade
   - Even as technological progress exacerbates inequality

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Households and Production

Households

- Households have heterogeneous multidimensional skills, $\theta \sim F(\theta)$
- Goods $i = 1, ..., N$
- Identical weakly separable preferences:

$$U(\theta) = u(C(\theta), n(\theta))$$
$$C(\theta) = v(\{c_i(\theta)\})$$

Technology

- Old technology: $G(\{y_i\}, \{n(\theta)\}) \leq 0$
- New technology: $G^*(\{y_i^*\}; \phi)$
- Note that only old technology demands labor

New Technology Examples

Trade

$$G^*(\{y_i^*\};\phi) = \sum_i \bar{p}_i(\phi) y_i^*$$

Robots and Tasks

$$G^*(y_f^*, y_m^*) = \phi y_f^* + y_m^*$$
$$y_f = \left(\int y_i^\rho \right)^{\frac{1}{\rho}}$$
$$y_i = \int a_i(\theta) n(\theta) dF(\theta) + a_i(m) y_m$$

Taxation

- **Household budget:**

$$\sum_i p_i c_i = w(\theta)n(\theta) - \underbrace{T(w(\theta)n(\theta))}_{\text{Non-linear income tax}}$$

- **Firm profits:**
    - Old Technology:

$$\sum_i p_i y_i - \int w(\theta)n(\theta)dF(\theta)$$

    - New Technology:

$$\sum_i p_i^* y_i^*$$

- **Ad-valorem taxes:**

$$p_i = (1 + t_i^*)p_i^*$$

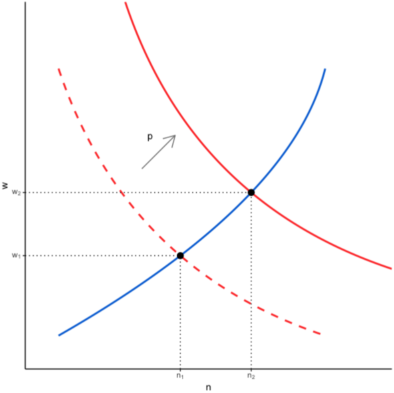
Equilibrium

- An equilibrium consists of...
  - an allocation, $c \equiv \{c(\theta)\}$, $n \equiv \{n(\theta)\}$, $y \equiv \{y_i\}$, $y^* \equiv \{y_i^*\}$
  - prices and wages, $p \equiv \{p_i\}$, $p^* \equiv \{p_i^*\}$, $w \equiv \{w(\theta)\}$
  - taxes, T and $t^* \equiv \{t_i^*\}$
- ...such that
  - households maximize utility
  - firms maximize profits
  - markets clear
  - $p_i = (1 + t_i^*)p_i^*$ for all i
  - the government's budget is balanced

Key Mechanism

Equilibrium wages depend on prices: $w(p, n; \theta)$

- Optimally tax new technology to affect wages
- E.g. Tax robots to increase labor demand in routine tasks, increasing wages



Social Welfare

- Very general social welfare function: Depends on the distribution of utility

  $\Longrightarrow$ Anonymity: Indifferent to trading places

- Allocation of consumption and labor $(c, n) \implies U \equiv \{U(\theta)\}$
- Utility schedule induces a CDF over utilities, summarized by $\bar{U} \equiv \{\bar{U}(z)\}$, where quantiles $z \in [0, 1]$
- Social welfare function $W(\bar{U})$ is a strictly increasing function of the distribution of utility

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Literature

	Production Factors	$T(w(\theta)n(\theta);\theta)$	$p_i = p_i^*$
First Best		$T(\theta)$	Yes
D & M (1971)	$(\{n(\theta)\};\{y_i\})$	$\tau(\theta)w(\theta)n(\theta)$	Yes
Naito (1999)	$(n(\theta_L), n(\theta_H)); \{y_1^f, y_2^f\})$	$T(w(\theta)n(\theta))$	No
C & W (2020)	$(\{n(\theta)\};\{y_i\})$	$T(w(\theta)n(\theta))$	No

Additionally, Costinot and Werning (2020) introduce

- Quantitative optimal tax formulas: $p_i = (1 + t_i^*)p_i^*$; Naito (1999) and others [1] present qualitative insights: $p_i \neq p_i^*$
- Rich mutli-dimensional heterogeneity

[1] Other recent papers include Guerreiro, Rebelo and Teles (2017) and Thuemmel (2018)

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Value of Innovation

- Is technological change always desirable?

$$\underbrace{\Delta\phi}_{\text{AI innovation}} \rightarrow$$

$$\underbrace{\frac{\partial}{\partial\phi}\left|\frac{\partial G^*(\{y_i\},\phi)}{\partial y_i}\right| > 0}_{\text{Easier to make robots, } y_i} \rightarrow$$

$$\underbrace{\Delta\frac{G^*_{y_i}}{G^*_{y_1}} \propto \Delta p_i}_{\Delta \text{ eq. price of robots}} \rightarrow$$

$$\underbrace{\Delta\{w(\{p_i\},\{n(\theta)\},\theta)\}}_{\Delta \text{ wage dist.}}$$

Value of Innovation

Government's problem:

$$V(\phi) = \max_{(c,n,y,y^*,p,p^*,w,T,t^*,\bar{U})\in\Omega_R} W(\bar{U})$$

subject to

$$G^*(y^*;\phi) = 0$$

- Consider the introduction of AI: $\phi \to \phi + d\phi$

$$\frac{dV(\phi)}{d\phi} \underbrace{=}_{Envelope} -\gamma \frac{\partial G^*}{\partial \phi}$$

Value of Innovation

- Consider the introduction of AI: $\phi \rightarrow \phi + d\phi$

$$\frac{dV(\phi)}{d\phi} \underbrace{=}_{Envelope} -\gamma \frac{\partial G^*}{\partial \phi}$$

If $\gamma > 0$,

$$\frac{dV}{d\phi} > 0 \iff \frac{\partial G^*}{\partial \phi} < 0$$

- $\gamma > 0$:
  - Taxes on factors of production can always restore original MRS within new technology firm
  - Income tax can be used to redistribute gains
- Even with distributional concerns, innovations always desirable!

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Efficiency vs. Redistribution

- Can the government improve welfare by taxing robots (y_i^*) in new technology firms?

$$\underbrace{\delta t_i^*}_{\text{Tax } y_i^*} \rightarrow$$

$$\underbrace{\delta p_i}_{\delta \text{ eq. prices}} \rightarrow$$

$$\underbrace{\delta\{n^D(\{w(\theta)\},\{p_i\},\theta)\}}_{\delta \text{ eq. labor demand}} \rightarrow$$

$$\underbrace{\delta\{w(\{p_i\},\{n(\theta)\},\theta)\}}_{\delta \text{ eq. wage dist.}}$$

- $\delta\{w(\{p_i\},\{n(\theta)\},\theta)\}$ can also loosen incentive constraints
- δt_i^* can be paired with δT^* for welfare improvements

Efficiency vs. Redistribution

Taxes on new technology goods are optimal if for any variation $(\delta t_i^*, \delta T)$:

$$\underbrace{-\sum_i t_i^*(p_i^* y_i^*)\delta \ln y_i^* - \int \tau(z)\bar{x}(z)\delta \ln \bar{n}(z)dz}_{\text{Marginal cost of efficiency loss}}$$

$$= \underbrace{\int [\bar{\lambda}(z) - 1]\bar{x}(z)\left[(1-\tau(z))\delta \ln \bar{w}(z) - \frac{\delta T(z)}{\bar{x}(z)} - \sum_i \frac{p_i \bar{c}_i(z)}{\bar{x}(z)}\delta \ln p_i\right] dz}_{\text{Marginal benefit from redistribution}}$$

- $\bar{\lambda}(z)$ denotes the welfare weight on all households with income z
- Formula in terms of observable wages z

Efficiency vs. Redistribution

Can simplify formula for special cases where $\delta T = 0$ and $\delta \bar{U} = 0$.
In the case for $\delta \bar{U} = 0$, the optimal tax on robots simplifies to:

$$\tau_i^* = \int \tau(z) \frac{\bar{x}(z)}{p_i^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z) + 1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}\bigg|_{\delta G^* = 0} dz + O(\bar{\varepsilon}^2)$$

with $\delta G^* = 0$ a budget-balanced variation, $\omega(z) \equiv \frac{\bar{w}'(z)}{w(z)}$ the slope of the wage schedule, and $\bar{\varepsilon}$ such that $|\varepsilon_H(z)|, |\varepsilon_M(z)| < \bar{\varepsilon}$ for all $z \in [0, 1]$.

- Sufficient statistics and no subjective welfare weights
- Estimated using Acemoglu and Restrepo (2017) to be $t_i^* \in [1\%, 5.6\%]$

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Comparative Statics

In a simple environment,

optimal Rawlsian tax t^* on robots is decreasing with the productivity ϕ of new technology firms

- Cheaper robots may lead to a higher share of robots in the economy, more inequality, but a *lower* optimal tax on robots
  - Relative wages become less responsive to an increase in robots: $\frac{\partial}{\partial \phi}\left|\frac{d\ln(\omega)}{d\ln y_r^*}\right| < 0$ (less effective at reducing inequality)
  - With a greater supply of robots, the demand for robots becomes more elastic: $\frac{d}{d\phi}\left|\frac{d\ln y_r}{d\ln p^r}\right| > 0$ (efficiency cost)

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Discussion

Contributions

- Brings structure to debate about whether to tax robots and trade
- Shows that deviations from production efficiency are optimal in very general setting with few structural assumptions
  - Allows multidimensional heterogeneity!
- Optimal tax formulas with sufficient statistics
  - Advances qualitative insights of earlier literature to provide quantitative policy implications

Limitations

- Steady state results
- Hard to interpret the value of multi-dimensional heterogeneity when consumers have identical preferences