Robots, Trade, and Luddism

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Table of contents

Introduction

Model Environment

Literature

Results
  Value of Innovation
  Optimal Technology Regulation
  Comparative Statics

Discussion
Table of contents

Introduction

Model Environment

Literature

Results
  Value of Innovation
  Optimal Technology Regulation
  Comparative Statics

Discussion
Motivation

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

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 “predisburse”, 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
Table of contents

Introduction

Model Environment

Literature

Results
  Value of Innovation
  Optimal Technology Regulation
  Comparative Statics

Discussion
Households and Production

Households

- Households have heterogeneous multidimensional skills,
  $\theta \sim F(\theta)$
- Goods $i = 1, \ldots, N$
- 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

\[ G^*\left(\{y_i^*\}; \phi\right) = \sum_i \bar{p}_i(\phi)y_i^* \]

Robots and Tasks

\[ G^*(y_f^*, y_m^*) = \phi y_f^* + y_m^* \]

\[ y_f = \left( \int y_i^\rho \right)^{1/\rho} \]

\[ y_i = \int a_i(\theta) n(\theta) dF(\theta) + a_i(m)y_m \]
Taxation

- **Household budget:**
  \[ \sum_i p_i c_i = w(\theta) n(\theta) - T(\underbrace{w(\theta) n(\theta)}_{\text{Non-linear income tax}}) \]

- **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

  \[ U \equiv \{ U(\theta) \} \]

- Allocation of consumption and labor \((c, n) \Rightarrow U \equiv \{ U(\theta) \}\)

- Utility schedule induces a CDF over utilities, summarized by \( \tilde{U} \equiv \{ \tilde{U}(z) \} \), where quantiles \( z \in [0, 1] \)

- Social welfare function \( W(\tilde{U}) \) is a strictly increasing function of the distribution of utility
Table of contents

Introduction

Model Environment

Literature

Results
  Value of Innovation
  Optimal Technology Regulation
  Comparative Statics

Discussion
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

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\(^1\)Other recent papers include Guerreiro, Rebelo and Teles (2017) and Thuemmel (2018)
Table of contents

Introduction

Model Environment

Literature

Results

Value of Innovation

Optimal Technology Regulation

Comparative Statics

Discussion
Value of Innovation

▶ Is technological change always desirable?

$$\Delta \phi \rightarrow$$

AI innovation

$$\frac{\partial}{\partial \phi} \left| \frac{\partial G^* (\{y_i\}, \phi)}{\partial y_i} \right| > 0 \rightarrow$$

Easier to make robots, $y_i$

$$\Delta \frac{G^*_{y_i}}{G^*_{y_1}} \propto \Delta p_i \rightarrow$$

$\Delta$ eq. price of robots

$$\Delta \{w(\{p_i\}, \{n(\theta)\}, \theta)\} \rightarrow$$

$\Delta$ 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: \( \phi \rightarrow \phi + d\phi \)

\[ \frac{dV(\phi)}{d\phi} \underset{Envelope}{=} -\gamma \frac{\partial G^*}{\partial \phi} \]
Value of Innovation

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

$$\frac{dV(\phi)}{d\phi} \Rightarrow \frac{-\partial G^*}{\partial \phi}$$

Envelope

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!
Table of contents

Introduction

Model Environment

Literature

Results
  Value of Innovation
  Optimal Technology Regulation
  Comparative Statics

Discussion
Efficiency vs. Redistribution

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

$$\delta t_i^* \rightarrow \delta p_i \rightarrow \delta\{n^D(\{w(\theta)\}, \{p_i\}, \theta)\} \rightarrow \delta\{w(\{p_i\}, \{n(\theta)\}, \theta)\}$$

- Can also loosen incentive constraints

- $\delta t_i^*$ can be paired with $\delta T^*$ for welfare improvements
Efficiency vs. Redistribution

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

\[- \sum_i t_i^* (p_i^* y_i^*) \delta \ln y_i^* - \int \tau(z) \bar{x}(z) \delta \ln \bar{n}(z) dz\]

Marginal cost of efficiency loss

\[= \int [\bar{\lambda}(z) - 1] \bar{x}(z) \left[ (1 - \tau(z)) \delta \ln \bar{w}(z) - \frac{\delta T(z)}{\bar{x}(z)} - \sum_i \frac{p_i \bar{c}_i(z)}{\bar{x}(z)} \delta \ln p_i \right] dz\]

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 $\delta \tilde{U} = 0$. In the case for $\delta \tilde{U} = 0$, the optimal tax on robots simplifies to:

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

with $\delta G^* = 0$ a budget-balanced variation, $\omega(z) \equiv \frac{\tilde{w}'(z)}{w(z)}$ 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 $t_i^* \in [1\%, 5.6\%]$
# Table of contents

- Introduction
- Model Environment
- Literature
- Results
  - Value of Innovation
  - Optimal Technology Regulation
  - Comparative Statics
- Discussion
Comparative Statics

In a simple environment,

optimal Rawlsian tax $t^*$ on robots is decreasing with the productivity $\phi$ 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)
Table of contents

Introduction

Model Environment

Literature

Results
  Value of Innovation
  Optimal Technology Regulation
  Comparative Statics

Discussion
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