Steering Technological Progress (with J. Stiglitz)

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Motivate

Motivation:

- since Industrial Revolution: technological progress has improved living standards 20x
- in recent decades: fruits of progress shared increasingly unevenly
- Artificial Intelligence threatens most (all?) labor with redundancy

BUT: let's not be fatalistic!
progress is not exogenous but (for now, at least) driven by human decisions

Research Question

How should we steer technological progress while taking into account its distributive impact?

Premise

Assumptions:

- **Premise:** it is desirable for economy to offer well-paying jobs
  - either because large-scale redistribution is impossible, for incentive or political-economy reasons
  - or because work directly provides certain forms of utility
- **Examples:**
  - Google Maps: has enabled millions to earn income as drivers
  - Google Waymo: threatens to put millions out of their jobs

  (Note to Google: *don't be evil*!)

Contribute

Existing Literature:

- **Endogenous/directed technical change**
- **Optimal taxation**

Define

Definitions/Categories of Technological Change:

- factor-biased (vs. neutral) technological change:
  MP of one factor rises more than that of another factor
- factor-saving (vs. factor-using) technological change:
  MP of a given factor declines (rises) in equilibrium
- extreme: factor-replacing technological change:
  a given factor can be fully replaced by another factor

Setup

General Setup:

- $i = 1, ...I$ agents
- $j = 1, ..., J$ goods
- $h = 1, ..., H$ factors of production
- factor endowments $\ell^i = (\ell^{i1}, ..., \ell^{iH})'$ add up to aggregate $\ell = \sum_i \ell^i$
- agent i utility $u^i\left(c^i\right)$ over vector of consumption $c^i = (c^{i1}, ..., c^{iJ})'$
- representative firm with vector of technology parameters $A = \left(A^1, \ldots, A^K\right)$ draws output vector $y = \left(y^1, ..., y^J\right)'$ from CRS production possibilities

$$y = F\left(\ell; A\right) \quad \text{or more generally} \quad y \in F\left(\ell; A\right)$$

  where $A = \left(A^1, \ldots A^K\right)$ is a vector of technological parameters
- social planner with weights $\left\{\theta^i\right\}$ on individual utilities

$$\max W = \sum_i \theta^i u^i\left(c^i\right)$$

First-Best

First Best:

- costless redistribution
- social planner with weights $\left\{\theta^i\right\}$ on individual utilities

$$\max_{c^i, A} W = \sum_i \theta^i u^i \left(c^i\right) \quad \text{s.t.} \quad \sum_i c^i = F\left(l; A\right)$$

- FOC

$$\theta^i u' \left(c^i\right) = \lambda \quad \forall i$$
$$\lambda \cdot F_{A^k}\left(\ell; A\right) = 0 \quad \forall k$$

$\rightarrow$ redistribution is not an issue, focus on production efficiency

Laissez Faire Equilibrium

Market Structure:

- consumers obtain income from factor compensation $p \cdot c^i = w \cdot \ell^i$
- assume each firm can pick technology parameter A

$$\max_{\ell, A} \Pi = p \cdot F(\ell; A) - w \cdot \ell$$

- FOC

$$p' F_\ell (\ell; A) = w$$
$$p \cdot F_{A^k} (\ell; A) = 0 \quad \forall k$$

- if technology is parameterized (w.l.o.g.) such that it can be subjected to linear taxes then

$$\Pi = p \cdot F(\ell; A) - w \cdot \ell - \tau \cdot A$$

  and FOC

$$p \cdot F_{A^k} (\ell; A) = \tau^k \quad \forall k$$

Constrained Planner

Constrained setup (assume single good for now):

- assume planner cannot redistribute at all so $c^i = w \cdot \ell^i = F_\ell(\ell; A) \cdot \ell^i$
- constrained planner with weights $\{\theta^i\}$ on individual utilities

$$\max_A W = \sum_i \theta^i u^i \left(F_\ell(\ell; A) \cdot \ell^i \right)$$

- FOC

$$\sum_i \theta^i u^{i\prime} \left(c^i \right) F_{\ell A^k}(\ell; A) \cdot \ell^i = 0 \quad \forall k$$

$\rightarrow$ benefit of technology for factors weighted by MU of factor owners

Implement Constrained Planner

- Competitive Equilibrium with taxes (using Euler's theorem):

$$F_{A^k}(\ell; A) = F_{\ell A^k}(\ell; A) \cdot \ell = \tau^k \quad \forall k$$

- Constrained Planner:

$$\sum_i \theta^i u^{i\prime}\left(c^i\right) F_{\ell A^k}(\ell; A) \cdot \ell^i = 0 \quad \forall k$$

- in combination
  - w.l.o.g. normalize θ^i's so $\sum_i \theta^i = 1$
  - then θ^i defines probability measure E_i

$$\tau^k = -\left(\sum_i \theta^i u^{i\prime}\left(c^i\right) F_{\ell A^k}(\ell; A) \cdot \ell^i - E_i\left[u^{i\prime}\left(c^i\right)\right] F_{\ell A^k}(\ell; A) \cdot \ell\right)$$
$$= -\sum_h F_{\ell^h A^k}(\ell; A)\, E_i\left\{\left[u^{i\prime}\left(c^i\right) - E_i u^{i\prime}\left(c^i\right)\right] \ell^{hi}\right\}$$

- intuition: tax takes into account
  - how much progress benefits each factor
  - what the relative MU of different agents is
  - and how much of each factor each agent owns

Enhance Labor

Examples of labor-using technologies:

- intelligent assistants (IAs) – across a variety of fields
  - including Google Maps
  - AR devices to upskill workers
- platforms to intermediate unmet labor demand
- ...

Implement in Practice

Wide variety of angles of implementation:

- create more awareness/"nudge" enterpreneurs/innovators
- government-sponsored research, innovative government programs
- stakeholder participation in decision-making: unions, work councils, ...
- taxes and subsidies on innovation

Simple Example

Simple Example:

- two agents: $i =$worker, capitalist with log utility
- own one unit of labor, capital
- CES production with factor-augmenting technology

$$F(\ell; A) = \left[\left(a_K(A)\,\ell_K\right)^{\rho} + \left(a_L(A)\,\ell_L\right)^{\rho}\right]^{\frac{1}{\rho}}$$

  where A determines weight on capital- vs labor augmenting progress
  $\rightarrow$ defines a locus s.t. w_L/w_K increasing in A
- constrained planner chooses

$$\max_A \theta^L \log w_L + \theta^K \log w_K$$

Proposition

The planner's optimal choice of A is a strictly increasing function of the planner's relative weight on workers θ^L/θ^K.

Simple Example:

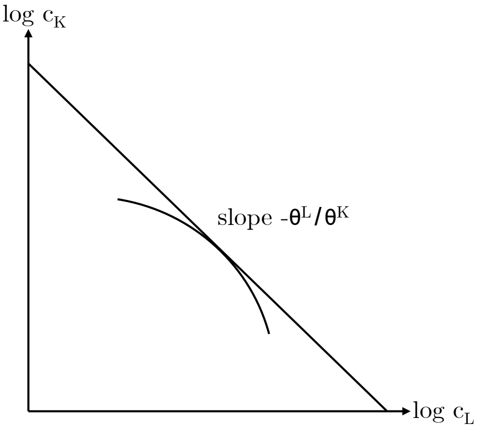

Figure: Innovation possibilities frontier and welfare isoquants

Work & Meaning

Some argue that work provides not only income but also non-monetary benefits

- identity
- meaning
- status
- social connections

→ important factors for steering technological progress

Setup

Setup to capture non-monetary factor "rents:"

$$U^i = u^i\left(c^i\right) + d^i \qquad \textbf{where} \qquad c^i = F_L\left(\ell; A\right)\cdot \ell^i,\ d^i = v\left(A\right)\cdot \ell^i$$

- constrained planner's problem

$$\max_A \sum_i \theta^i \left[u^i\left(F_\ell\left(\ell; A\right)\cdot \ell^i\right) + v\left(A\right)\cdot \ell^i\right]$$

- optimization FOC

$$\sum_i \theta^i \left[u^{i\prime}\left(c^i\right) F_{\ell A^k}\left(\ell; A\right) + v_{A^k}\right]\cdot \ell^i = 0 \quad \forall k$$

$$\underbrace{\sum_i \theta^i u^{i\prime}\left(c^i\right) F_{\ell A^k}\left(\ell; A\right)\cdot \ell^i}_{\text{factor compensation}} + \underbrace{\sum_i \theta^i v_{A^k}\cdot \ell^i}_{\text{non-monetary}} = 0 \quad \forall k$$

Corollary

The better we have addressed the material problem (monetary factors), the more steering progress should focus on non-monetary factors

Conclude

Conclusion:

- growing prominence of labor-saving progress, esp. given the rise of AI
- limits to redistribution
- makes steering technological progress increasingly desirable