Artificial Intelligence, Worker-Replacing Technological Change and Income Distribution

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Technological possibilities and utility possibilities

Consider arrival of a new technology that replaces workers. Would their standard of living *necessarily* decline?

CASE 1) If the world is 1st-best, then everybody is perfectly insured against new technologies, and expansion in production possibilities automatically implies that everybody is better off

→ unanimity about desirability of new technology

Technological possibilities and utility possibilities

In the real world: behind every great innovation lurks an equally great imperfection in risk markets

- majority of workers replaced by machines did NOT write insurance contracts against being replaced

→natural role for redistribution to *emulate missing markets* rather than interfering with markets

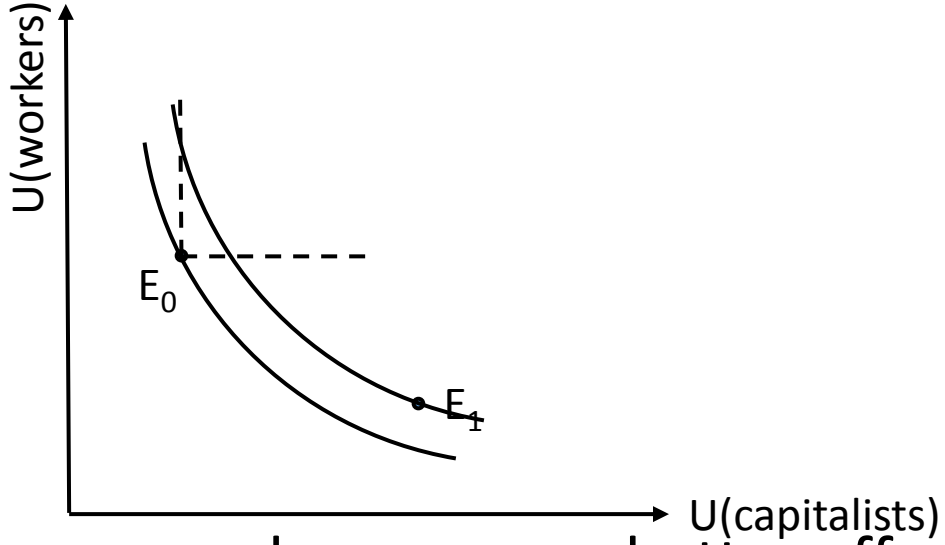
Significant reasons why risk markets are missing:

- information problems, including difficulty of describing future state space (easier to deal with ex-post than ex-ante)
- providing incentives for innovator (also constraints ex-post redistribution)

Technological possibilities and utility possibilities

Consider arrival of a new technology that replaces workers. Would their standard of living *necessarily* decline?

CASE 2) If (i) the world is 1st-best *ex-post* and (ii) redistribution is *costless*, the utility possibilities frontier (UPF) moves out, even if competitive equilibrium wage decreases:

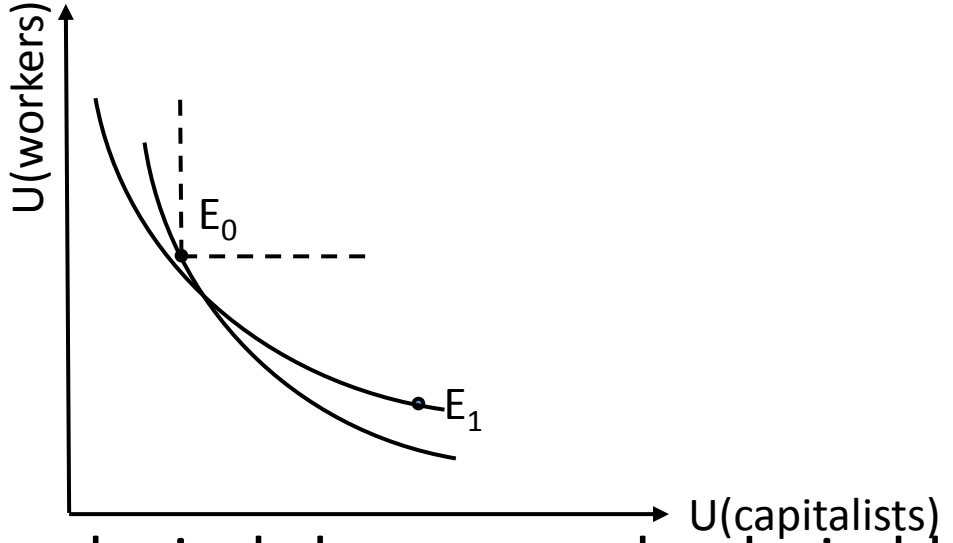


→ Redistribution can make everyone better off

Technological possibilities and utility possibilities

Consider arrival of a new technology that replaces workers. Would their standard of living *necessarily* decline?

CASE 3) If (i) the world is 1st-best ex-post but (ii) redistribution is *limited or costly*, the *constrained* utility possibilities frontier (UPF) may not lie outside the original schedule:



→ Limiting technological change may be desirable for workers

→ Resistance to innovation among those who lose out

Technological possibilities and utility possibilities

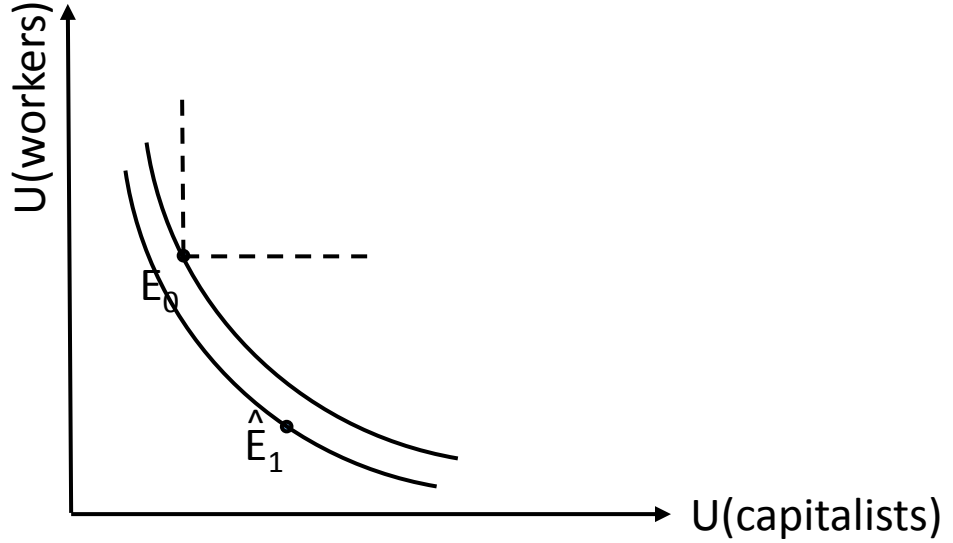
Important question: How costly is redistribution?

- almost surely, distortions introduced by redistribution are sufficiently small that innovation *could* be Pareto-improving
- changes in institutions/rules of the game also affect sharing of social benefits of innovation (e.g. intellectual property rights)

Technological possibilities and utility possibilities

Consider arrival of a new technology that replaces workers. Would their standard of living *necessarily* decline?

CASE 4) If the world is *not 1st-best*, the utility possibilities frontier may move inwards (even with costless redistribution):



→ Limiting technological change may be desirable for everyone

Technological possibilities and utility possibilities

More generally: the 1st-best UPF is the outer envelope of all conceivable constrained UPFs, which reflect all conceivable institutional regimes, e.g.:

- explicit tax & redistribution systems, UBI
- intellectual property regimes
- social norms (e.g. about charity or social equity)

as well as the role of any market imperfections, e.g.:

- informational frictions
- market arrangements (e.g. market power)
- rigidities in factor reallocation or in prices

→ changing institutions or addressing market imperfections may change workers' welfare

Incentives for innovation and welfare

No 1st welfare theorem for innovation

→ private returns to innovation ≠ social returns

CASE 5) Privately optimal innovation may shift the utility possibilities frontier inward (even with costless redistribution)

→Intervening in the innovation process may generate Pareto improvements

(Example: high-frequency trading)

Critical question: public policy

What public policies can ensure that everyone is better off?

Roadmap:

(A) Model of redistribution in a first-best economy

(B) Model of IP regimes when costless redistribution unavailable

(C) Some broader remarks

Separate question, not considered in this presentation:
Will these public policies emerge out of our political processes?

Worker-replacing technological change

(A) Redistribution in a first-best economy

Assume constant returns to scale production function, e.g. Y = F(K, H + M)

- Y is output, K is capital, H is human labor
- consider a technology to produce machine labor M at cost γ
- machines are *worker-replacing* because H and M are perfect substitutes

In competitive equilibrium: $w = F_L$

Two Questions:

1) What does worker-replacing technological change do to wages?
2) What can public policy do about it?

Machine labor and factor earnings

Proposition 1: Machine Labor and Factor Earnings in the Short Run (before other factors adjust): adding a marginal unit of machine labor reduces human wages but increases returns of complementary factors in a zero-sum manner

Euler's Theorem: $(H + M)F_L(\cdot) + KF_K(\cdot) = F(K, H + M)$

Additional unit of M: $F_L + (H + M)F_{LL} + KF_{KL} = F_L$

or simplified: $\underbrace{(H + M)F_{LL}}_{decline\ in\ wage\ bill} + \underbrace{KF_{KL}}_{increase\ in\ return\ to\ K} = 0$

→ adding machine labor creates redistribution toward complementary factors

= *pecuniary externality*

→ increased returns for complementary factor owners are like *unearned rents*

→ compensating workers simply undoes these pecuniary externalities

Machine labor and factor earnings

Results on zero-sum redistribution in Proposition 1 hold for any factors, e.g.:

- Labor vs capital
- Labor vs land
- Unskilled labor vs skilled labor (if the latter cannot be replaced by machines)
- Labor vs entrepreneurial rents

for factors that are substitutes: returns decline (e.g. routine labor)

→ policy can undo the redistribution by taxing unearned factor rents

→ taxes on previously accumulated factors are *non-distortionary*
(they automatically identify out-of-equilibrium returns)

→ machine labor plus redistribution yields, at the margin, a Pareto-improvement

Panglossian world: singularity

Labor is most important factor of production

→ scarcity of labor = biggest constraint on output

→ machine labor makes this factor easily reproducible

Proposition 2: Machine Labor and Singularity: if machine labor is sufficiently cheap and all other factors are also reproducible, the economy experiences a singularity, leading to:

- exponential growth driven by factor accumulation (AK-style)
- human wages unchanged, but human labor share → 0

→ outcome benign if workers care about absolute level of labor earnings

The return of scarcity

Although singularity may lead to significant growth, it is likely it will eventually be limited by scarcity of other non-reproducible factors,
e.g. land or energy – Y = F(H + M, K, land)

Proposition 3: Machine Labor and Scarcity of Factors in the Long Run: if there are non-reproducible factors, they will limit growth via factor accumulation

- human wages fall (as long as H and M substitutes)
- owners of non-reproducible factors absorb all the rents
- at the margin, redistribution from workers to other factor owners zero sum

NOTE: taxes on non-reproducible factors are by definition non-distortionary

→ at the margin, machine labor *plus* redistribution to undo pecuniary externalities generates a Pareto improvement!

The return of scarcity

Proposition 3 holds for all non-reproducible factors, no matter if used on production or consumption side

Example: worker-replacing progress makes land prices go up

→ workers worse off even if their productivity on the production side is unchanged

Intellectual property rights and redistribution

(B) Model of IP regimes when costless redistribution unavailable

If outright redistribution is infeasible, intervention to steer technological progress may act as a 2^{nd}-best device

Assume we have a distortionary tax τ leading to capital $K(\tau)$, and machine labor $M(t)$ is function of patent life t, affecting speed of progress

Maximizing W w.r.t. τ and $z \geq z^*$, $M(z^*) = 0$ where z is length of patent

Maximizing well-being of workers

Define $\tau(M)$ as value of tax, redistributed to workers, which keeps workers just as well off. Workers' income I is given by

$I = w + \tau K(\tau)/H$

$d\tau/dM = -LF_{LL}/K\,(1 - \eta)$

Where η is elasticity of capital supply

Three groups of individuals: workers, capitalists, innovators

As long as elasticity of capital supply is not too large, we can always increase z and compensate workers

Maximizing well-being of workers

- Denote growth rate $g(z, \tau)$, function of the length of the patent and tax rate, assume $b(z, \tau)$ fraction of output that can be appropriated by innovator, then p.d.v. of income of workers approximately given by

$$Y^* = (1 - b(1 - \tau))(1 - c(g))/(1 + g - \delta)$$

If we choose $\{z, \tau\}$ to maximize Y^*, in general, the optimum will not be a corner solution in which innovation necessarily hurts workers

We can extend that to include capital, skilled and unskilled workers.

Implication: in general, innovation *can* improve well-being of workers

Innovation, market imperfections and welfare

Transition may be complicated by market imperfections, e.g. AD externalities:

- Markets on their own are not good at structural transformation
- General result: with mobility frictions and rigidities technological change can be welfare-decreasing (Greenwald-Stiglitz *et al)*

Example: Rapid innovation in agriculture and the Great Depression:

- Fewer workers needed
- Resulting in marked decline in agriculture income
- Leading to large decline in demand for urban products
- What *might* have been a Pareto improvement turned out to be immiserizing technological change, as both those in the urban and rural sector suffered

→ massive government intervention (World War II) ultimately facilitated transition

= example of successful industrial policy (not only Keynesian stimulus)

Further policies and institutional regimes

(C) Tax and transfer policies:

- Wage subsidies, expanded earned-income tax credit, universal basic income (UBI)
- Carbon tax: encourages resource- rather than worker-saving innovation
  - Would simultaneously address two of most serious global problems
- Elimination of tax deduction for interest and the imposition of a tax on capital—to induce more capital-augmenting innovation (assuming incomplete shifting)

Spending polices:

- More spending on public research
  - With government appropriating returns
  - Directing research towards resource-saving innovation and away from labor-saving innovation
- Increase in public investments with high labor demand

Further policies and institutional regimes

Changes in institutions:

- Narrowing breadth and duration of patents
  - and circumscribing use of patents to create monopolies
- More effective anti-trust laws and enforcement

Special focus on non-market institutions in the service sector:

- Economy will evolve towards service sector, chiefly education, health, and other public services
- Value of those services is largely determined by public institutions not markets
- If we value those services highly—pay good wages, provide good working conditions, and create sufficient number of jobs—that will also limit growth in market income inequality

Conclusions

Worker-replacing technological change:

- is unambiguously positive in a first-best economy
  or if coupled with redistribution that undoes pecuniary externalities
  - scope for redistribution facilitated by windfall gains on complementary factors
  - easy to achieve Pareto improvement

- market imperfections and limits on redistribution worsen the calculus
  - Pareto improvement (or even any improvement) no longer ensured
    → may lead to resistance from those in society who lose out
  - broad set of 2nd-best policies desirable, including changes in IP rights

- with sufficient instruments, Pareto improvement is possible and innovation is always desirable