

# **The Macroeconomics of AI**

**(based on joint work with Anton Korinek)**

Joseph Stiglitz  
INET/IMF  
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# Broad perspective

- AI is just a change in technology—perhaps a dramatic one
  - Both replacing labor
  - And augmenting labor—increasing its power (sometimes called IA, intelligence assisting machines)
- Raising questions about change in shape of sectoral and aggregate production functions
  - Analysis can be embedded in model of localized technological change
- Except for issue of singularity (where machines are smarter, stronger, and cheaper than humans) analysis is little different from standard analysis of technological change
  - Though magnitude of changes are such that they may force us to think more deeply about the problems

# Big concern

- Growth of labor-replacing robots will lead to even more inequality and unemployment, so bad that society will actually be worse off, even if a few individuals are better off
  - Machines have long been stronger than humans, better able to do many physical jobs
  - Computers are better at processing large amounts of information
  - AI means that robots may even be better at learning
  - Extent to which they can replace or outperform humans in immediate future uncertain—large variance in estimates
  - Alternative perspective: robots (AI) will be labor augmenting, increasing productivities of large proportion of population
  - This paper sets problem in more abstract analysis of consequences of economy wide labor replacing robots

# Outline of approach and results

- Will employ a series of related models to bring out key insights
- Some of these are well known, others less so
- All are very stylized, and can be greatly enriched
- In next 4 slides, I will summarize major results, but then present the analysis in what I hope is a more pedagogic manner

# Case I. No government intervention

- Without government intervention, there can be welfare immiserizing technological change
  - It is possible that most individuals are worse off
    - Such an outcome can arise if there are significant intersectoral mobility costs
    - It can occur whether there are efficiency wages limiting wage reductions or not
  - It is even more possible that with any inequality averse social welfare function, social welfare is decreased
    - This is true even with individualistic social welfare functions, so long as there is some good (land) which is not being augmented (enough) by the process of technological change

# No government intervention: dynamics

- Analysis predicated on endogenous determination of factor bias of innovation
- Without government intervention, there *may* be a self-equilibrating process which limits the reduction in, say, the share of unskilled labor; **but there are conditions under which this process does not work**
  - **But with efficiency wages, there is a market bias towards excessive labor saving innovation, i.e. towards a dynamic equilibrium with too much unemployment**
    - **Each firm doesn't take into account the effect of its innovation policy on the aggregate unemployment rate—typical case of a *macro-economic externality***
      - **Broader perspective: there is no presumption that the market is efficient in the pace or direction of innovation, selection of research projects**
      - **There are systematic bias**
    - **This bias may be especially large in agency models, where manager makes decision on R & D, and puts excessive weight on his personal costs of managing unskilled workers. (standard governance result)**

# Dynamics

- The dynamics even in a simple model looks markedly different from that in a standard growth model, and main entail oscillatory convergence

# Case II: Government Intervention

- With government intervention, normally everyone can be made better off
  - There are a range of interventions, including tax and intellectual property policies
  - Revenues from taxes can be used to supplement pay of unskilled labor in service sector jobs that are unlikely to be replaced by AI and for training to transition into sectors unaffected by AI
  - Myopic monetary policy may exacerbate periods of unemployment
- Rich research agenda ahead: optimal AI, employment, wage, active labor market, and IPR policies

# I. No presumption that innovation is welfare enhancing

- No first theorem of welfare economics when technology is endogenous
  - Arrow and Debreu assumed fixed technology
- Much of support for market economy based on innovation
  - Schumpeter argued for advantages of monopoly
  - Subsequent research showed that all of presumptions underlying Schumpeter's analysis were wrong (monopolies would be temporary, contest to be monopolist ensured fast pace of innovation, contestability ensured that monopolist couldn't exploit market power)

# Presumption that market economies on their own are not efficient in innovation

- Subsequent work explained why presumption *against efficiency*
  - Innovation as a public good
    - IPR restricted dissemination, use, even pace of innovation (most important ingredient into research is knowledge)
  - Innovation is inherently risky, marked by imperfect information and incomplete insurance markets
    - Greenwald-Stiglitz 1986 showed that whenever markets were incomplete and information was imperfect, markets are not constrained Pareto efficient
  - Knowledge can be viewed as a form of information
    - Inefficiency in the production of knowledge
  - Also, fixed costs associated with innovation gives rise to imperfect competition (sometimes can be modeled as monopolistic competition, sometimes as oligopolistic competition)

## II. This paper explores one dimension of these inefficiencies related to AI: Factor Biased Innovation

- Series of simple models (variants of models already in the literature)
- Central argument: **tendency for excessive “labor saving innovation”**
- **Combining standard model of efficiency wages (explaining unemployment) with standard theories of biased technological change**

(Based on Stiglitz, “Unemployment and Innovation,” NBER Working Paper 20670, November 2014 and “Samuelson and the Factor Bias of Technological Change,” *Samuelsonian Economics and the Twenty-First Century*, M. Szenberg et al, eds., Oxford University Press: New York, 2006, pp. 235-251 and Stiglitz and Greenwald, *Creating a Learning Society: A New Approach to Growth, Development, and Social Progress*, New York: Columbia University Press, 2014. Reader’s Edition published 2015, and extensive earlier literature)

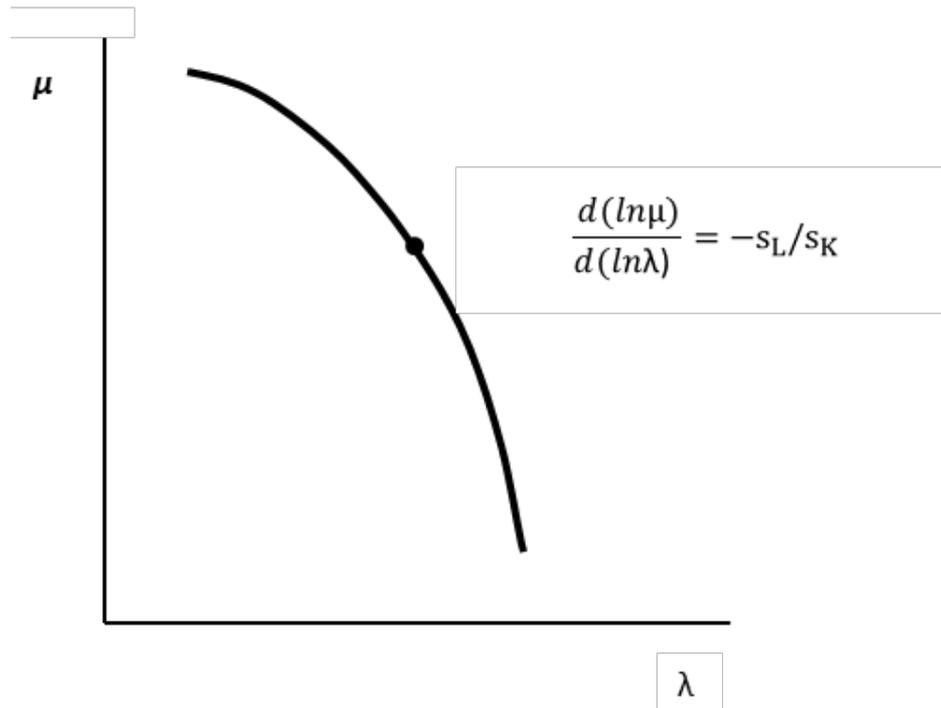


Figure 1

$$Q = F(\mu K, \lambda L)$$

where  $\{\mu, \lambda\}$  are capital and labor augmenting innovation, respectively

# Simple model: fixed coefficients technology (results easily generalized)

$$Q/K = b, Q/L = a$$

Innovation frontier: given  $a_t, b_t$

$$(1) b_{t+1} = z(a_{t+1})$$

Cost minimization entails

$$\text{Min } w/a + r/b$$

Implying

$$Z \equiv d \ln z / d \ln a = -s_L / s_K$$

# Broad interpretation

- **Costs as perceived by “decision maker”**
  - **Agency issues**
    - Managerial costs of labor
    - Search costs for labor
      - Interpretation of “scarcity of labor” (Habakkuk, 1962, and Salter, 1962)
- **Differences between these costs and social (shadow) prices will play a role in the following discussion**
  - **When there is unemployment, shadow price of labor differs from market price**
  - **Importance of macroeconomic externalities**

# Cost minimization

In general, firm has to think of dynamic path of factor prices. Two simplifications

- a. Steady state—firm believes wages increase smoothly at a given rate and cost of capital will be fixed; firm's cost minimization sustains that steady state equilibrium.
  - b. if knowledge produced at  $t$  for  $t + 1$  becomes publicly available at  $t + 2$ , then firm only focuses on “private” benefits of innovation, which occur at time  $t + 1$ .
- With symmetric equilibrium, all firms do same thing; most of following discussion focuses on symmetric equilibrium
  - May be more than one steady state equilibrium
  - In more general model, direction of innovation could differ across sectors
  - In more general model, innovation changes shape of production function
    - **Localized technological change (Atkinson-Stiglitz, 1969) emphasizes innovation as specific to particular activities, changing shape of production function**
      - **History matters—episode of low interest rates can have long lasting effects**

# Characterization of cost minimization

- With concave innovation frontier, **cost minimization implies that larger share of labor, more labor saving innovation; the larger the share of unskilled labor relative to skilled labor (at “perceived prices”) the more skilled biased technological change (see figure)**
- If endogenously determined bias of technological change works as it should, as wages get low, focus is on capital and resource augmenting technical change
  - Limiting decline in share of labor (in stable equilibrium) and in inequality
  - (Can describe dynamics with standard wage-setting mechanism: system stable so long as elasticity of substitution is less than unity)

# III. Consequences of labor saving innovation

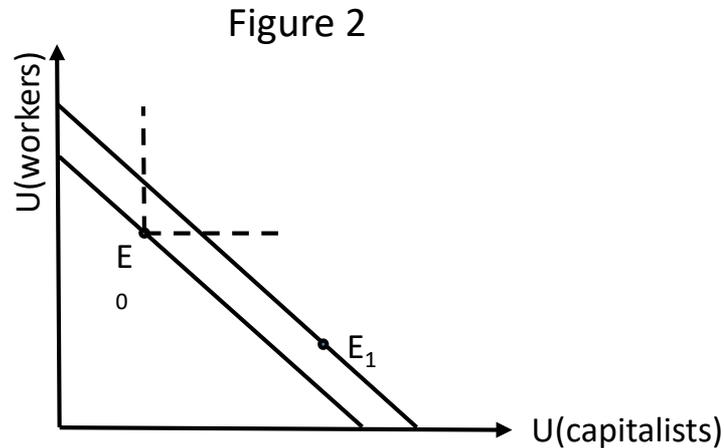
- **If the economy is able to achieve full employment, equilibrium wage is lowered—workers worse off**
- **With inequality averse social welfare function, social welfare lowered unless there is redistribution**
  - Redistribution may be costly—in which case it may be impossible to achieve welfare improvement
  - Welfare enhancing redistributions are economically feasible—the question is, will they occur
    - Increased wealth of “capitalists” increases their ability
      - to resist redistributions
      - to reduce progressivity of taxation or make it regressive (as has happened in US)
      - Inducing firms to engage in more rent-seeking behavior, increasing inequality still further

(Based in part on Kornek and Stiglitz, 2017, “Artificial Intelligence and Its Implications for Income Distribution and Unemployment,” forthcoming NBER volume)

# Technological possibilities and utility

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

1) If (i) the world is 1<sup>st</sup>-best and (ii) redistribution is *costless*,  
the utility possibilities frontier (UPF) moves out (even if competitive  
equilibrium wage decreases):

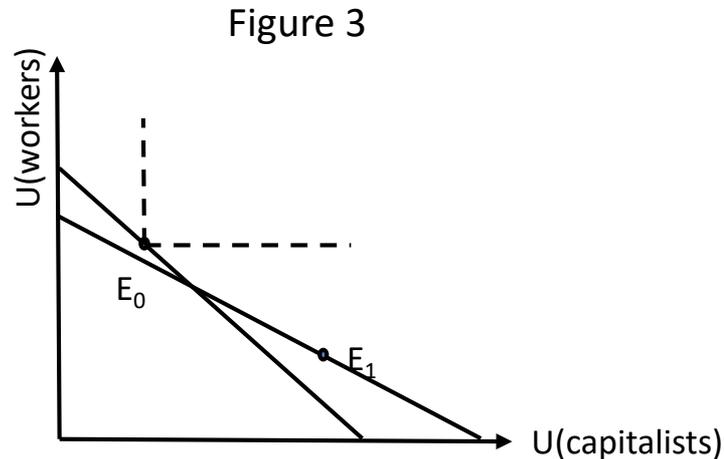


→ Redistribution can ensure that everyone is better off

# Technological possibilities and utility

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

2) If (i) the world is 1st-best but (ii) redistribution is limited, the constrained utility possibilities frontier (UPF) may not lie outside the original schedule:



→ Limiting technological change may be desirable for workers and for social welfare

# Technological possibilities and utility

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

- explicit redistribution systems
- intellectual property regimes
- market arrangements (e.g. market power)
- social norms (e.g. about charity or social equity)

→ changing any of these institutions may improve workers' welfare

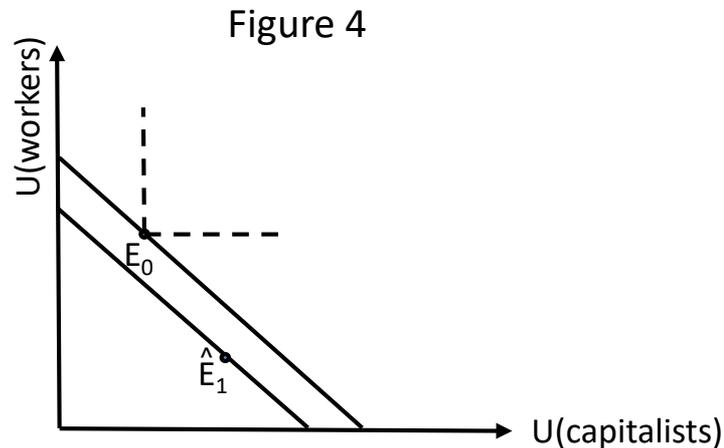
→ If redistribution is limited, may have to rely more on other institutional changes

→ Limits on IP limit rents that accrue to innovators; may also limit pace of innovation

# Technological possibilities and utility

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

3) If the world is *not 1<sup>st</sup>-best*, the utility possibilities frontier *may* move inwards (even with costless distribution):



→ Limiting technological change may be desirable for everyone

# Incentives for Innovation and Welfare

No 1<sup>st</sup> welfare theorem for innovation: Privately optimal innovation may shift the utility possibilities frontier inward (even with costless redistribution)

→ Intervening in the innovation process may generate Pareto improvements

(Examples: high-frequency trading; markets focusing on unskilled labor replacing innovation, even when shadow price of labor is low, ignoring importance of carbon innovation)

# Critical question: public policy

- Are there public policies which would ensure that everyone would be better off?
- Political economy: will these policies emerge out of our political processes?

We focus only on first question.

Constructs two simple models analyzing:

- (a) What happens when machines replace workers?
- (b) What are long run consequences of different policies?

# IV. Machine Labor and Factor Earnings

**Proposition 1: Machine Labor and Factor Earnings** (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:  $\underbrace{(H + M)F_{LL}}_{\text{decline in wage bill}} + \underbrace{KF_{KL}}_{\text{increase in return to K}} = 0$

→ adding machine labor creates redistribution toward complementary factors  
= *pecuniary externality*

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

# Machine Labor and Factor Earnings

Proposition 1 holds for all factors in the production function, e.g.:

- Labor vs capital
  - Labor vs land
  - Unskilled labor (replaced by machines) vs skilled labor
  - Labor vs Entrepreneurial rents
- policy can undo the redistribution by taxing unearned rents
- taxes on previously accumulated factors are non-distortionary (they automatically identify out-of-equilibrium returns)
- at the margin, 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)
- unchanged level of wages, but human labor share  $\rightarrow 0$

→ 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

**Proposition 3: Machine Labor and Return of Scarcity:** if there are non-reproducible factors, they will eventually limit growth

- human wages fall; owners of non-reproducible factors absorb all the rents
- at the margin, redistribution from workers to non-reproducible factor owners is zero sum
- taxes on non-reproducible factors are by definition non-distortionary
- scope for non-distortionary redistribution; at the margin Pareto improvement
- Technological change gives rise to rents which can be taxed, and revenues used to compensate workers

# Malthusian perspective on the proliferation of artificial intelligence

- If basic human intelligence is made redundant and the marginal product of human labor would fall below the human subsistence level, if redistribution is deemed infeasible, society faces two unpleasant alternatives:
  - halting AI or
  - allowing Malthusian forces to play out.

Extended utilitarian traditions provide a way of approaching this choice

The scope for redistribution is facilitated by the fact that the changes in factor prices create windfall gains on the complementary factors and that should make it rather easy to achieve Pareto improvements

# Intellectual Property Rights and Redistribution

If outright redistribution is infeasible, intervention to steer technological progress may act as a 2<sup>nd</sup>-best device

Example: assume we have a distortionary tax  $\tau$  leading to capital  $K(\tau)$  and machine labor  $M(z)$  is function of patent life  $z$ .

$$Q = F(K(\tau), M(z) + H)$$

Government maximizes social welfare  $W$  w.r.t.  $\tau$  and  $z \geq z^*$ , where  $M(z^*) = 0$

# Maximizing well-being of workers

Define  $\hat{\tau}(M)$  as value of tax, redistributed to workers, which keeps workers just as well off. Representative worker income  $I$  is given by

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

Where  $w = F_L$  : workers' receive marginal product

Machines decrease marginal product (compete with humans).

Hence, as  $M$  increases,  $\tau$  must increase. But increase in  $\tau$  decreases capital stock, and that hurts workers.

**Proposition 4: So long as the elasticity of capital supply is not too large, we can always increase  $\tau$  and compensate workers**

# Reframing the issue (heuristic)

- Assume a 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:

**Proposition 5: In general, the optimal  $\{z^*, \tau^*\}$  entails  $g > 0$ .**

**i.e. t.c. *can* improve well-being of workers**, but pace of t.c. that maximizes workers likely to be well below maximal feasible pace, or even pace which maximizes well-being of innovators

# How to help ensure evolution of technology is likely to be welfare increasing

- Economy will be evolving towards service sector economy
- Among key service sectors are education, health, and other public services
- Value of those services is largely socially determined—not “just” a market process
- If we value those services highly—pay good wages, provide good working conditions, and create sufficient number of jobs—that will limit growth in market income inequality
  - Including jobs with limited skill requirements
  - Higher pay will result in such jobs having higher “respect”
  - Private sector wages will follow public sector wages
  - May need also to provide wage subsidy for low wage jobs, to encourage demand for such jobs and increase wages
- If elasticity of entrepreneurial services is low, we can impose high taxes to finance these jobs

# UBI not solution

- Human jobs provide not only income but also mental services in the form of meaning, status, and fulfillment
- If this is so, shift from focusing on pure redistribution of income to generation of jobs or other activities
- But this could be just a characteristic of current generation

- Under these conditions, benefits of growth can be shared equitably, and in ways that ensure full employment
  - Larger pie—so everyone can be better off
- Such an outcome is economically feasible
- But economy may not go in that direction
  - Politics matters
  - And even the conditions for economic feasibility are restrictive

# V. Labor saving innovations, efficiency wages, and unemployment

To analyze unemployment, need a “theory” of unemployment

Efficiency wages provides a simple well-grounded theory

With efficiency wages, labor saving innovations lead to higher unemployment and lower wages

$$Q = F(\mu K, \lambda L)$$

where  $\{\mu, \lambda\}$  are capital and labor augmenting innovation, respectively. In short run, we take capital,  $K$ , and labor,  $L$ , as fixed

Real wage  $w = \lambda [f - \kappa f']$ , where  $\kappa$  is effectively capital labor ratio ( $\mu K / \lambda L$ ). If firm takes  $K$  and  $\mu$  as given, this solves for employment  $E$ , as a function of  $w$  and  $\lambda$ . (Note in this context  $\kappa = K/E$ .)

Labor saving innovation shifts demand for labor down at each value of the real wage (for fixed  $\{K, \mu\}$ )

$$(1) E = \psi(w; \lambda)$$

where  $E$  is employment level

- Efficiency wage: the real wage is a function of the unemployment rate, which we write as  $w = \xi^*(U)$ , or since at any moment, the unemployment rate is just a function of the level of employment,

$$(2) w = \xi(E),$$

With  $\xi' > 0$ .

**Equilibrium is solution to (1) and (2).** By definition, Hicks labor saving innovation leads to lower  $w$  and employment (higher unemployment). Whether labor augmenting innovation as above leads to lower or higher wages depends on the elasticity of substitution.

# Private profit maximization leads to excessive labor saving innovation

Assuming that costless redistributions are possible, social welfare is maximized by maximizing national output with respect to  $\lambda$ , taking into account the effect of  $\lambda$  on the unemployment rate:

$$\max F(\mu K, \lambda(1 - U)L)$$

where  $U$  is the unemployment rate, i.e.,

$$\begin{aligned} d(\ln Q)/d(\ln \lambda) &= \{F_1 \lambda Z'K + F_2 [(1 - U) \lambda L] - w \lambda L dU/d(\ln \lambda)\}/Q \\ &= [r\mu K d(\ln \mu)/d(\ln \lambda) + (1 - U)L\lambda w - w \lambda L dU/d(\ln \lambda)]/Q \\ &= s_k d(\ln \mu)/d(\ln \lambda) + (1 - s_k)\{1 + d[\ln(1 - U)]/d(\ln \lambda)\} \end{aligned}$$

At the private sector optimization, this is  $<$  or  $>$  0 as  $dU/d \ln \lambda >$  or  $<$  0:

***There is excessive labor-augmenting innovation if the effect of innovation is to increase the unemployment rate, i.e. if  $\sigma < 1$ .***

If elasticity of substitution is less than unity, labor augmenting t.c. is labor saving.

Converse results hold if the elasticity of substitution is greater than one

# Complex dynamics of adjustment and multiple momentary equilibria

- High wages lead to labor augmenting innovation, reducing demand for labor, lowering wages
- Low wages lead to capital augmenting innovation, resulting in large increases in demand for labor from any given level of investment
- In life cycle model, if workers think (rationally) that the rate of return will be high, they will save (and invest) little, in which case wages will be low and the return to capital will be high
  - But if they believe that the rate of return will be low, they will save (and invest) a lot, in which cases wages will be high and return to capital will be low
  - Effects moderated by factor biased innovation
  - Multiplicity of momentary equilibrium easy to generate, but does not hold for all preferences, production functions
  - When there is multiplicity of momentary equilibrium, there are an infinite number of paths consistent with rational expectations

# Dynamics: simple case with fixed coefficients

and fixed savings rate (results can be generalized)

$$I = sQ = dK/dt$$

s is the savings rate, I is investment, and K is the capital stock

$$d \ln \mu / dt \equiv m = z(\Lambda)$$

m is rate of capital augmenting progress

$\Lambda$  is rate of labor augmenting progress

$$\Lambda \equiv d \ln \lambda / dt.$$

Choice of direction function of relative shares (as before)—taking limit to continuous time

$$Z(\Lambda) \equiv -d(\ln z)/d(\ln \Lambda) = s_L / (1 - s_L) \equiv \Phi(\kappa)$$

Where (as before)  $s_L$  is share of labor, which is just a function of the effective capital labor ratio,  $\kappa$ :

$$\kappa = \mu K / \lambda L$$

Can solve for  $\Lambda$  as a function of  $\kappa$ :

$$\Lambda = z^{-1}(\Phi(\kappa)) \equiv \theta(\kappa).$$

# Evolution of economy described by:

$$d \ln \mu / dt = m = z(\Lambda) = z(\theta(\kappa)).$$

$$d \ln \kappa / dt = d \ln K / dt + m - \Lambda - n$$

$$= S \mu (f(\kappa) / \kappa) + z(\theta(\kappa)) - \theta(\kappa) - n$$

Where  $n$  is the rate of growth of population

# Steady State

- $z(\theta(\kappa^*)) = 0$
- $\mu^* = [n + \theta(\kappa^*) - z(\theta(\kappa^*))] \kappa^* / S f(\kappa^*)$

Stable oscillatory dynamics

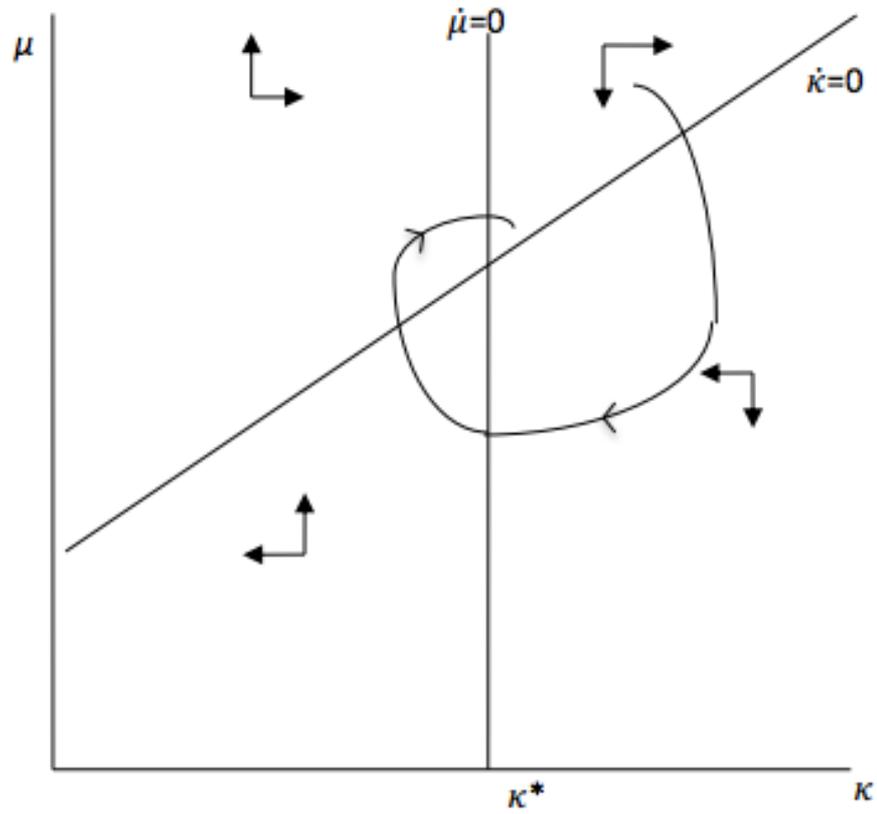


Figure 5a

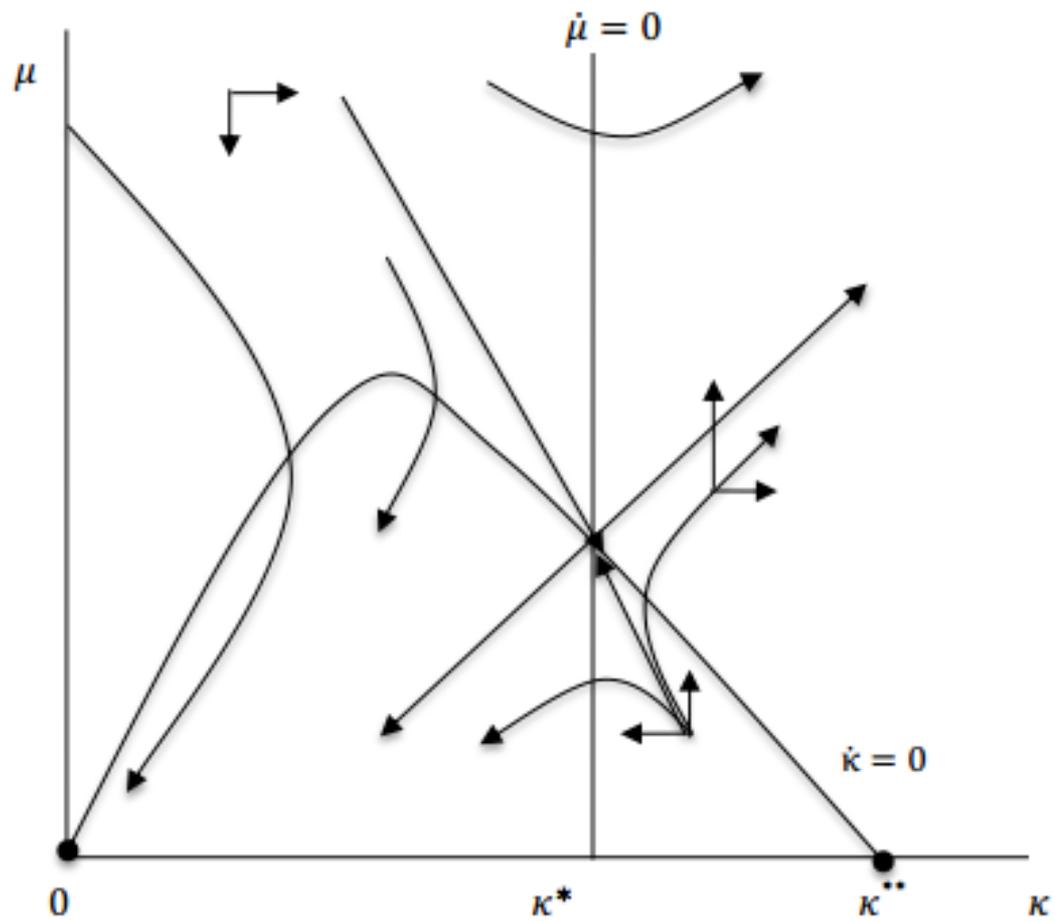


Figure 5b

# VI. Consequences of monetary policy in demand constrained macroeconomic equilibrium

Illustration of general point

- **Lower interest rate designed to stimulate investment**
- **But also lowers relative cost of capital (share of capital)**
  - Observed increase in return to capital related to monopoly/oligopoly rents
- **Induces labor augmenting innovation—which (if elasticity of substitution is less than unity) reduces demand for labor**
  - **Ambiguous effects in the short to medium run (benefit of more investment has to be set against cost of lower employment)**
  - **Making it possibly more difficult to restore economy to full employment**
- Intertemporal trade off in unemployment in demand constrained equilibrium
  - Investment, aggregate demand, and employment increases in short run
  - But labor required to meet future demand reduced
  - Not a problem if monetary and fiscal policy can restore economy to full employment
  - But is a problem if there are constraints, e.g. if future level of output is fixed, or if there are constraints on monetary and fiscal policy

## **VI. Sectoral reallocations can lead to innovation being Pareto inferior—and high unemployment**

**Discussion so far has ignored adjustment costs**

**With adjustments costs, even greater likelihood of welfare decreasing innovation, in absence of government interventions**

**There are government interventions that can ensure innovation is welfare increasing**

- **Combining Keynesian stimulation with industrial/sectoral policies**
- Another application of basic insight: what is individually rational may not be collectively rational when there are “market failures”
- Innovation is rife with market failures
- These can be viewed as macroeconomic externalities
  - Impacts of decisions in one sector on welfare of other sectors

# Simple model demonstrating this

Model provides explanation of what happened in Great Depression

- Technological change can affect different sectors differently, necessitating a reallocation of labor *in first best equilibrium*
- But **reallocating labor is costly**
  - **This is natural real rigidity in the system**
- And there may be rigidities: in decentralized economy, individuals in sector requiring “outmigration” may not have resources to move to new location and to get necessary education
  - Their own human and financial capital (value of housing) may be impaired
  - They cannot buy insurance against these contingencies; and most individuals do not buy the incomplete insurance that they could buy through structured finance
  - Well understood capital market imperfections

(Based on D. Delli Gatti, M. Gallegati, B. Greenwald, A. Russo and J. E. Stiglitz, “Mobility Constraints, Productivity Trends, and Extended Crises,” *Journal of Economic Behavior & Organization*, 2012, 83(3): 375– 393 and "Sectoral Imbalances and Long Run Crises," in *The Global Macro Economy and Finance*, F. Allen, M. Aoki, J.-P. Fitoussi, N. Kiyotaki, R. Gordon, and J.E. Stiglitz, eds., IEA Conference Volume No. 150-III, Houndmills, UK and New York: Palgrave, 2012, pp. 61-97.)

# Disequilibrium impact on inequality

- Technological change has large distributive effects
- Destruction of value of physical and human capital
- Only if the individual could obtain perfect insurance at the time of birth (or before the conception of the innovation) would information about the advent of the job replacing innovation, and the advent itself, not be welfare reducing.
- But someone born as an unskilled worker today, even under these conditions where he could buy insurance, will be worse off than he would have been had there not been such a possibility—unless the government engages in ex ante lump sum redistributions to compensate the individuals for the decrease in ex ante expected utility.

# Clear parallels to situation today

Economy could be caught in a low level equilibrium trap

**Government can play an important role in increasing welfare, in some cases, a Pareto improvement, in others reducing inequality, improving the plight of workers**

Policies to facilitate transition and ensure a welfare enhancing long run equilibrium (with greater equality) include:

- Policies to increase wages of even low skilled jobs
  - High aggregate demand—to ensure low unemployment rate
  - Wage subsidy
  - Minimum wage—also would (together with other measures) help encourage innovations that increase productivity of labor at the bottom
  - High wages in public sector—to help drive up wages in economy more generally
    - Other policies to encourage attractiveness of such jobs and increase respect for them
  - “Wage share” tax: profit tax increased if wage share (appropriately defined) is lower
- Vastly expanded Earned income tax credit—to ensure that no one who works full time is in poverty
  - Does it make a difference whether *individuals or jobs* are subsidized?
- More effective anti-trust laws, more effectively enforced
- Reducing rents associated with patents
- Narrowing breadth and duration of patents
  - And circumscribing use of patents to create monopolies
- An increase in labor-demand increasing public investments

# Further policies: facilitating transition *and* shaping innovation

- Elimination of tax deduction for interest and the imposition of a tax on capital—to induce more capital augmenting innovation
- High carbon tax—to encourage resource saving innovation, at the expense of labor saving innovation
  - Would simultaneously address two of most serious global problems
- More reliance on public research
  - Directing research towards resource saving innovation and away from labor using innovation
  - With government appropriating returns

# Great Depression as an historical example

- Innovation in agriculture combined with price and income inelastic demand led to increase in supply, decrease in agricultural prices and income
- When pace of innovation was moderate and other circumstances favorable, individuals could migrate out of agriculture sector to urban sector—earlier in 20's, from 30% of population to 25% (a one-sixth decline)
- In late twenties, marked fall in prices (in some cases by 75%) and income (by more than 50%), with effects amplified by resulting financial sector distress: migration stopped—labor was trapped
  - Decreased demand for urban goods
  - With efficiency wages employment in urban sector decreased

# Basic Model

Two sectors (industry, agriculture)

$$(1) \beta\alpha = \beta D^{AA}(p, p\alpha) + E D^{MA}(p, w^*)$$

$$(2) H(E) = \beta D^{AM}(p, p\alpha) + E D^{MM}(p, w^*) + I$$

$\beta$  is the labor force in agriculture,  $(1 - \beta)$  is the labor force in industry,

$\alpha$  is productivity in agriculture,

$D^{ij}$  is demand from those in sector  $i$  for goods from sector  $j$

$w^*$  is the (fixed) efficiency wage in the urban sector,

$I$  is the level of investment (assumed to be industrial goods),

$p$  is the price of agricultural goods in terms of manufactured goods, which is chosen as the numeraire, and

$E$  is the level of employment ( $E \leq 1 - \beta$ );

and where we have normalized the labor force at unity.

$H(E)$  is the total production of industrial goods

(For simplicity, assume that profits are not consumed, e.g. because enterprises owned abroad)

# Equilibrium

- Demand equals supply of agricultural goods

Higher employment in manufacturing leads to higher demand for food, and hence higher  $p$ .

- Demand equals supply of manufactured goods

Higher price of agriculture goods leads to higher income in rural sector, and thus more manufacturing employment

Can be multiple equilibria

Most of analysis focuses on impact on (stable) equilibrium from parameter shifts that shift MM and AA curves

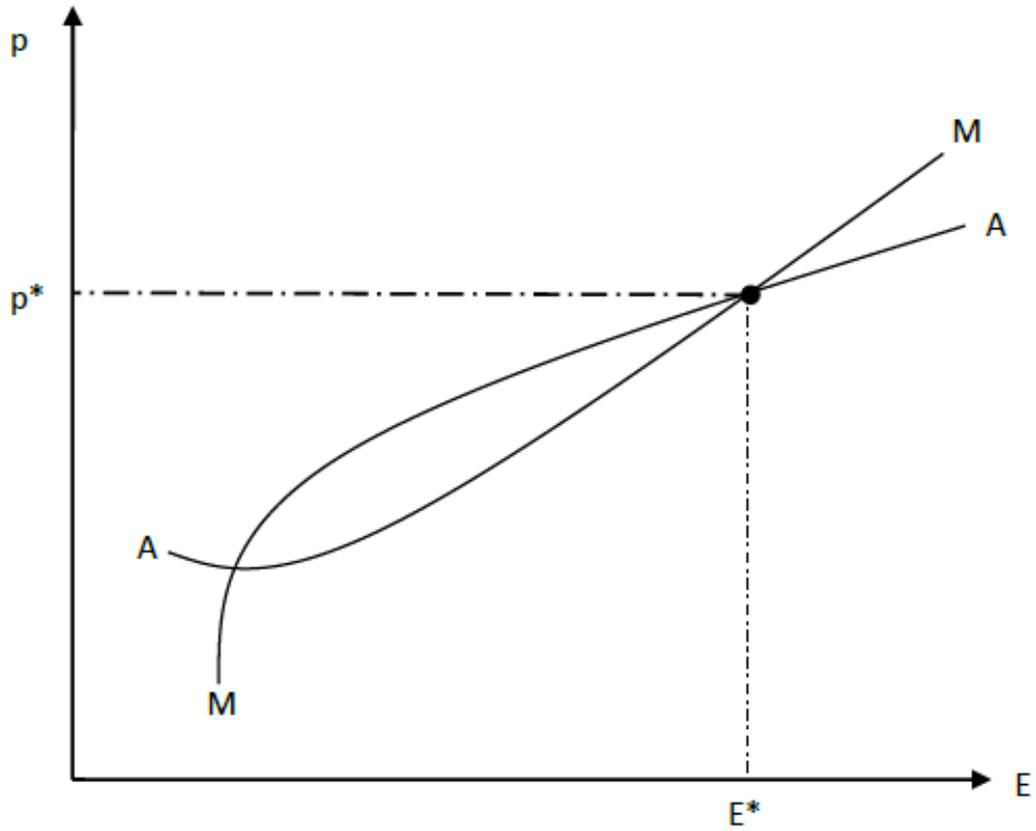


Figure 6

# Results

Normally (under stability condition, other plausible conditions) with immobile labor

***an increase in agricultural productivity unambiguously yields a reduction in the relative price of agriculture and in employment in manufacturing.***

The result of mobility-constrained agricultural sector productivity growth is an extended economy-wide slump

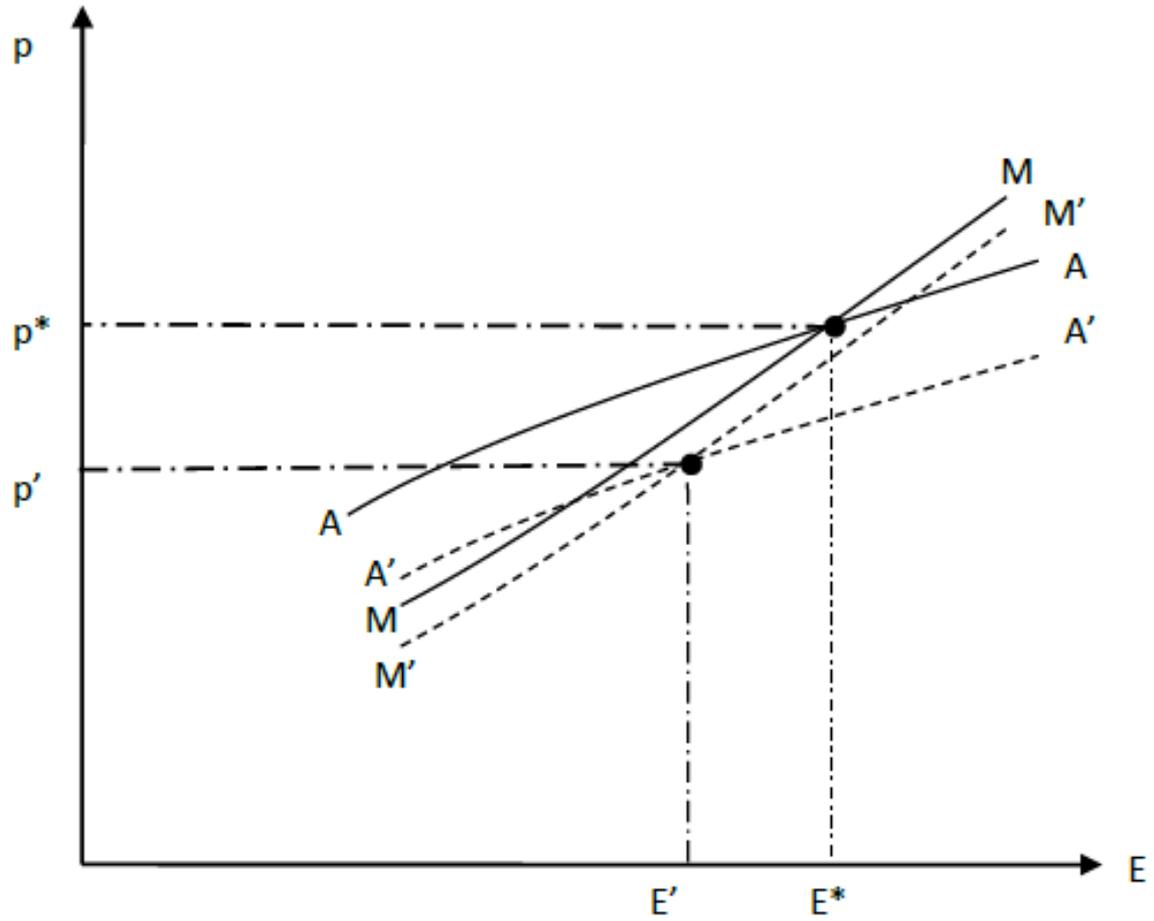


Figure 7: The effects of an increase in agricultural productivity

# Government Expenditures

- Under the stability condition, an increase in government expenditure increases urban employment and raises agricultural prices and incomes
  - In figure 7, productivity shock shifts employment from  $E^*$  to  $E'$
  - Keynesian stimulus brings economy back to  $E^*$

*Even though problem is structural, Keynesian policies work*

*Even more effective if spending is directed at underlying structural problem*

- Migration subsidy can help economy adjust, overcoming market imperfection

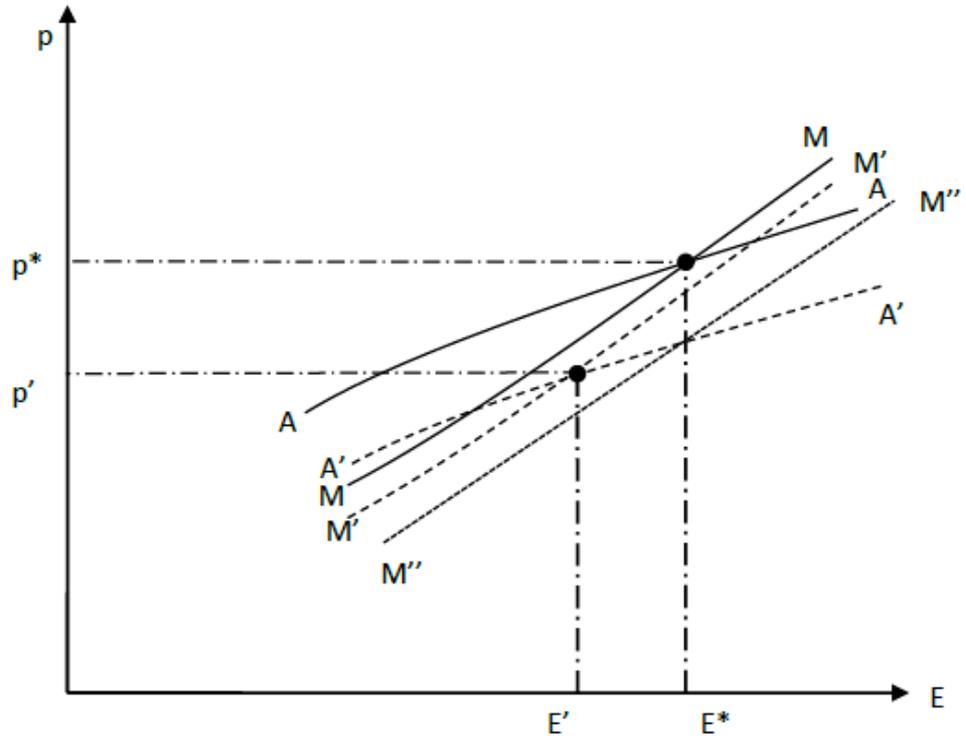


Figure 8: Impact of Keynesian stimulus:  
 an increase of  $G$  shifts the  $MM$  curve from  $M'M'$  to  $M''M''$   
 and increases both employment and rural prices

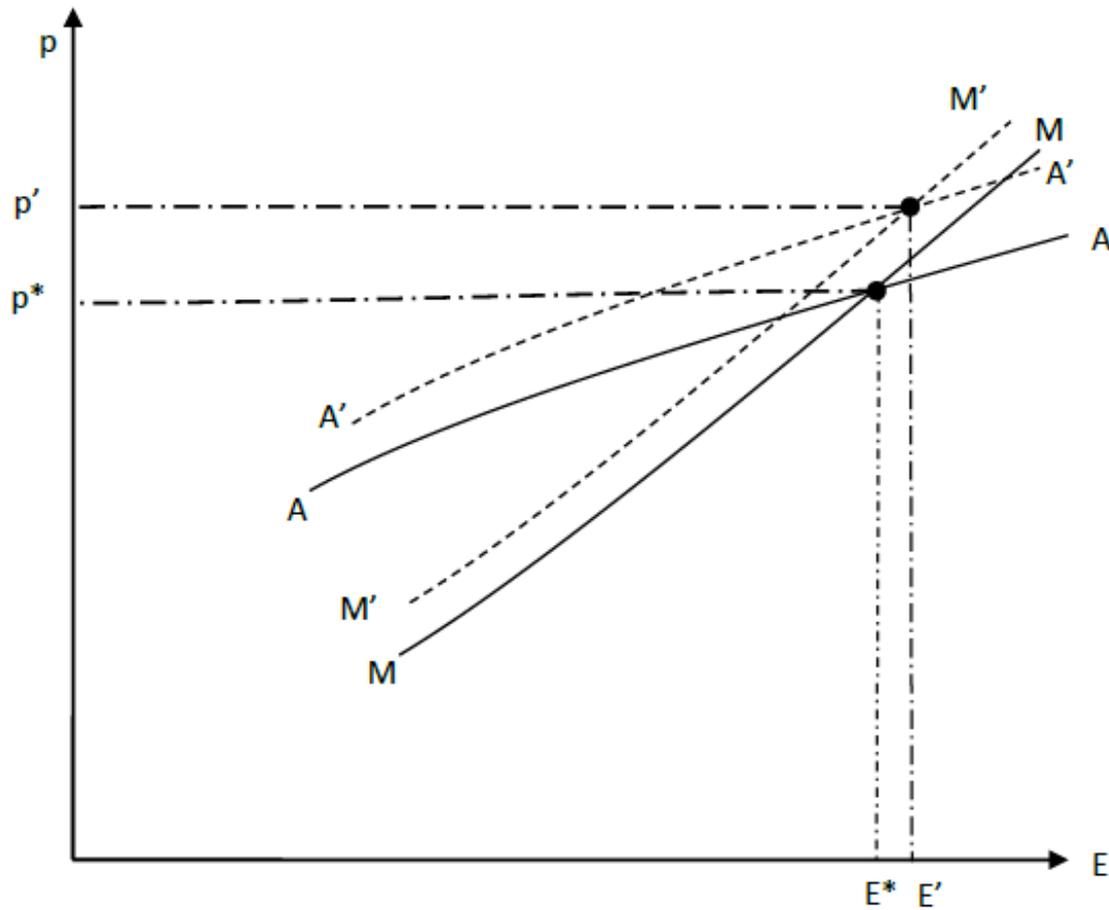


Figure 9: Effects of Migration Subsidy

# Emerging from the Great Depression

- New Deal was not big enough to offset negative effects of declining farm income
  - And New Deal was not sustained
    - Cutbacks in 1937 in response to worries about fiscal deficit led once again to a downturn
  - And much of Federal spending offset by cutbacks at state and local level
- WWII was a massive Keynesian stimulus
  - Moved people from rural to urban sector
  - Provided them with training
    - Especially in conjunction with GI bill
- ***It was thus an “industrial policy” as well as a Keynesian stimulus policy***
- Forced savings during War provided stimulus to buy goods after War
  - In contrast to the legacy of debt now

# Wages

In model, under normal conditions, lowering urban wages lowers agricultural prices and urban employment

- *High (rigid) wages are not the problem*
- *Lowering wages would lower aggregate demand—worsen the problem*
- *In this crisis, the US—country with most flexible labor market—has had poor job performance, worse than many others*

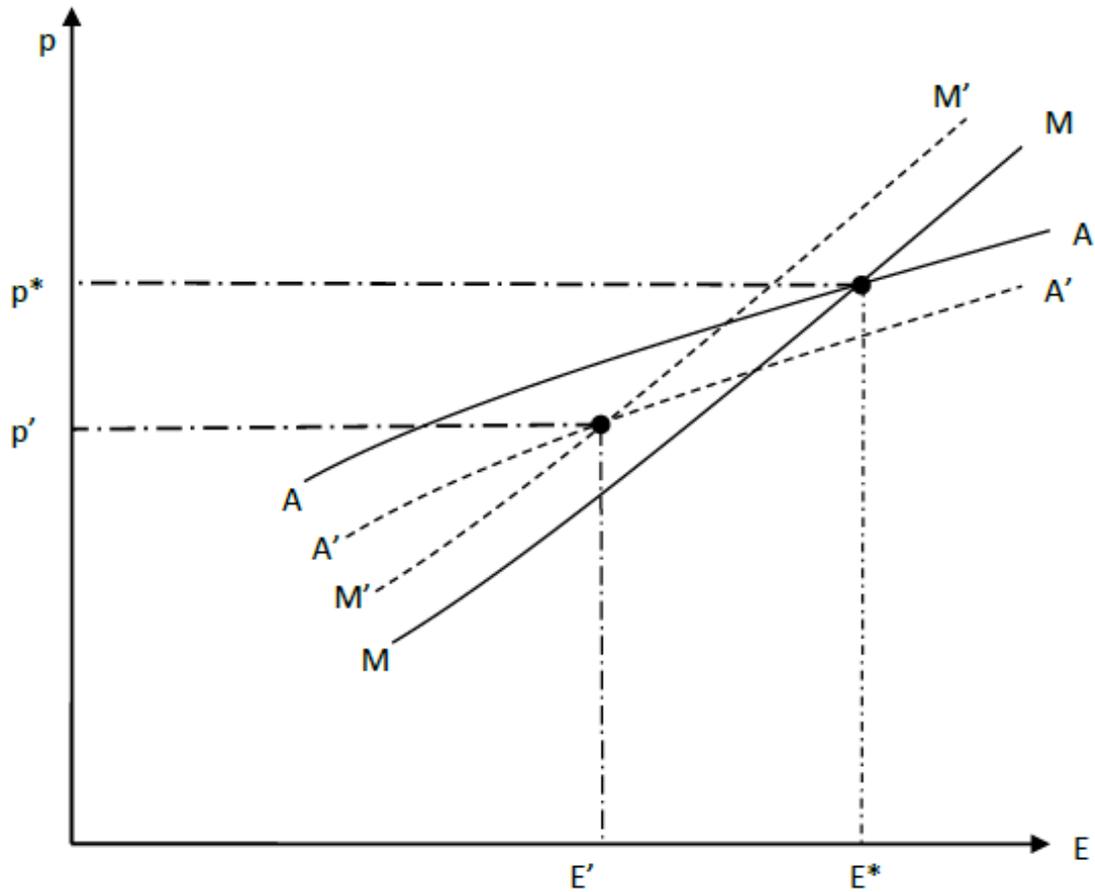


Figure 10: The effects of downward wage adjustments

# VII. Relationship between Technological Progress and Globalization

- Globalization can be viewed as a change in technology—expanding production possibilities
- Ideas presented here apply:
  - In standard neoclassical model, new equilibrium entails unskilled workers worse off in advanced countries (factor price equalization theorem, illustrated by figure 1)
  - Weakening of workers' bargaining power moves new equilibrium to an even more disadvantageous position
  - Argument that redistribution is costly implies we are in regime illustrated by figure 2—workers objecting to trade liberalization understandable
  - With imperfect risk and capital markets and frictions free trade may be Pareto inferior (Newbery Stiglitz 1984, Stiglitz 2017) (Figure 3)
    - Especially relevant for recent trade agreements: effect of TPP on GDP negligible, but it may still have had distributive effects

# Concluding Remarks: Theory of growth

- Solow reconciled disparity between warranted and natural rate of growth by assuming neoclassical production function
- Theory of biased induced innovation shows alternative way of reconciliation
  - With technology adjusting, even when at any moment there are fixed coefficients
- In Solow, distribution of income is determined by factor supplies, with given technology. Distribution of income plays no role in evolution of economy
- In fixed coefficients induced innovation model, efficiency wage theory determines distribution which affects evolution of economy
- Markedly different dynamics

# Concluding remarks: innovation and unemployment

- **Presumption that economy is not efficient in pattern of innovation**
  - **Excessive investment in labor saving innovations**
    - **Resulting in too high a level of unemployment, too low wages**
  - **Insufficient investment in innovations saving the planet**
- **Example of macroeconomic externality**
  - **Resulting in lower wages and higher unemployment**
- **Pace of innovation may not be sensitive to ability of economy to absorb “shocks”**
  - **Important non-linearities: if pace is too fast, innovation can lead to lower output, not just lower wages**

# Concluding remarks: policy

- **Wages affect evolution of productivity**
  - Wage compression policies of Scandinavia lead to increased productivity of unskilled workers (unskilled bias t.c.)
  - Minimum wages may have similar effects
  - Putting additional burden of fiscal and monetary policy to maintain full employment
- **Increasing carbon price may shift innovation towards those which save the planet**
- **May be desirable to have a tax on robots** (more generally, on labor saving innovations) to help internalize externality
- **May be desirable to stabilize pace of innovation** (variety of tools by which this may be done)
- **Monetary policy needs to be sensitive to effects on induced innovation**
  - May be trade-off between unemployment today and unemployment later
- **Active policies—Keynesian industrial policies—can lower unemployment, increase output, facilitate transitions**
- **In absence of active government policies, innovation from a decentralized market economy may be welfare reducing**
  - Especially if redistributions are constrained/costly

# Concluding Remarks

- **The more willing society is to support the necessary transition and to provide support to those who are “left behind,” the faster the pace of innovation that society can accommodate, and still ensure that the outcomes are Pareto and welfare improvements.**
- **A society that is not willing to engage in such actions should expect resistance to innovation, with uncertain political and economic consequences. (Korinek and Stiglitz, 2017)**