Unemployment, Welfare, and Innovation

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AEA Meetings, Philadelphia
January 2018

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: Adverse effects on wages, unemployment, and societal welfare

- 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**
  - **Cost minimizing point where elasticity of curve = relative shares (s_L/s_K)**
    - Analysis based on expectations (could be myopic or "rational")
    - Can exist multiple equilibria

(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)

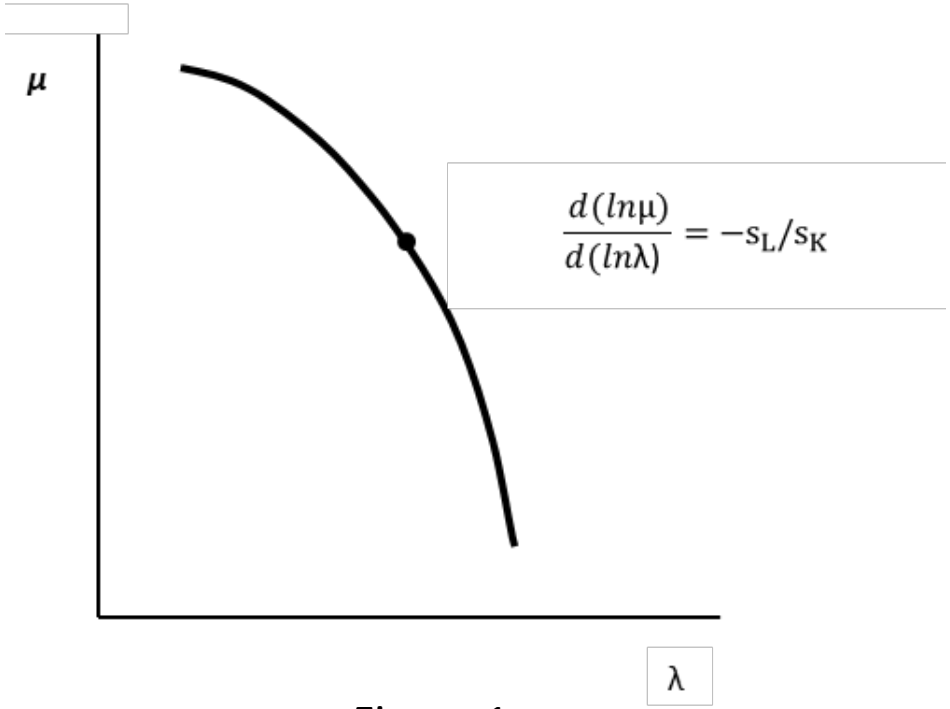

Figure 1

Q = F(μK, λL)
where {μ, λ} 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

Min $w/a + r/b$

Implying

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

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**

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**

Qualifications/assumptions

With convex innovation frontier, critical w/r at which there is a shift from capital augmenting innovation to labor augmenting innovation

Result holds regardless of structure of industrial organization (e.g. competitive, monopolistic equilibrium, oligopolistic equilibrium)

Firm has to think of dynamic path of factor prices: in example, just focuses on minimizing costs next period

- Relevant case 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.
- With symmetric equilibrium, all firms do same innovation, so spillovers irrelevant

In more general model, direction of innovation could differ across sectors

- **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**
- Most of following discussion focuses on symmetric equilibrium

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)

With redistributions, inclusive growth is possible but without redistributions, labor saving innovation is welfare decreasing

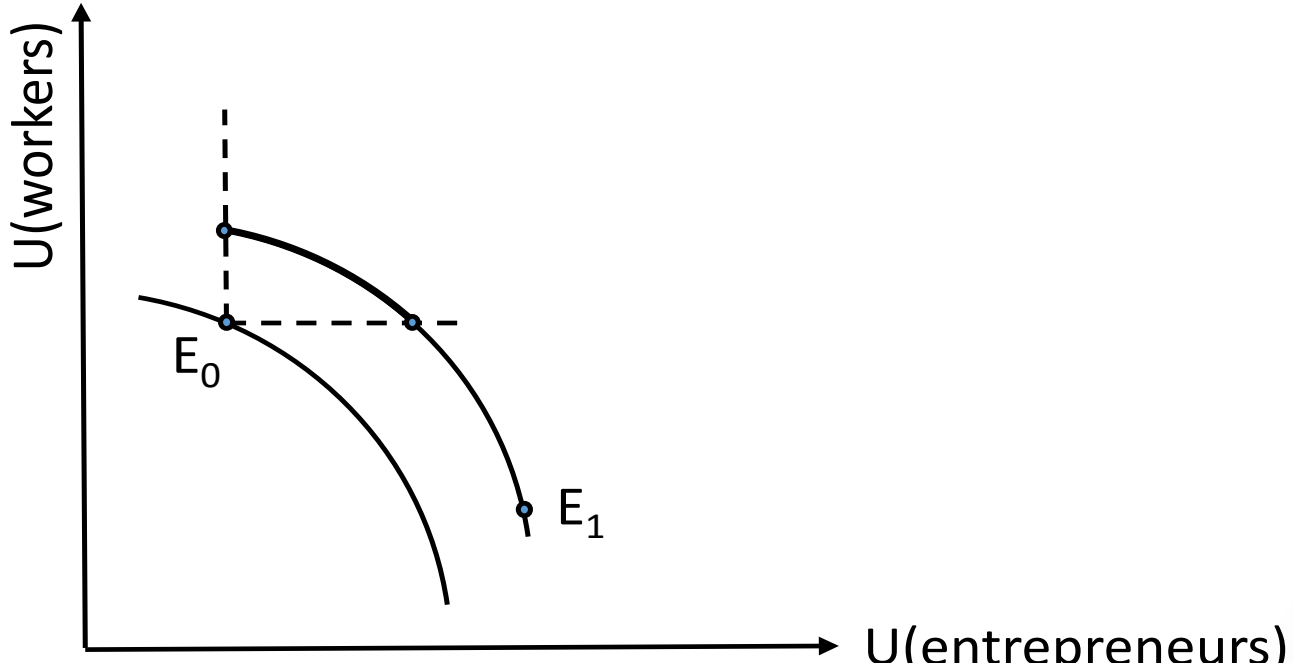

Figure 2

Technological possibilities and utility

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

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:

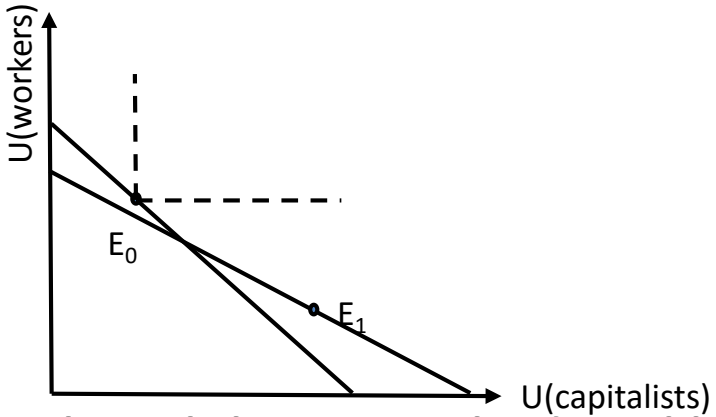

Figure 3

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

IV. 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

Real wage $w = \lambda [f - \kappa f']$, where κ is effectively capital labor ratio $(\mu K/ \lambda L)$.

- 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 if 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). Labor saving innovation leads to lower w and employment (higher unemployment)

V. 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 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**

(Labor augmenting innovation is labor saving if elasticity of substitution is less than unity)

- 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

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 rationale may not be collectively rational when there are "market failures"
- Innovation is rife with market failures

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
- 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.)

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

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

α 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 equilibrium

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

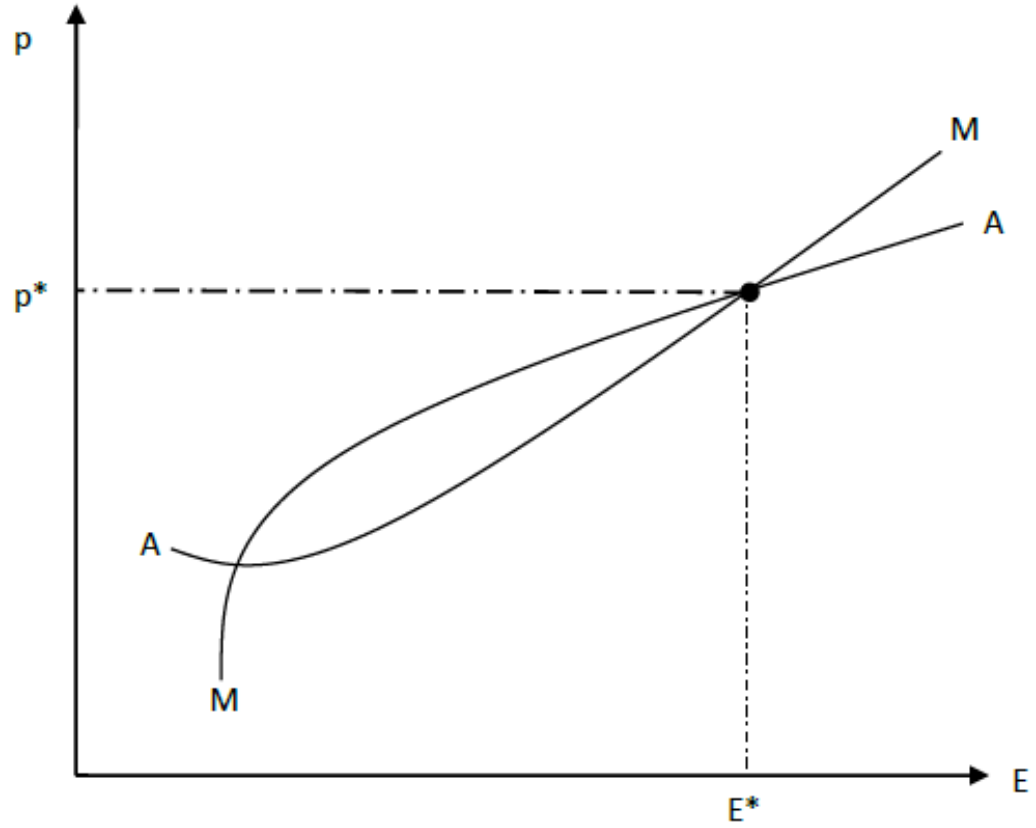

Figure 4

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

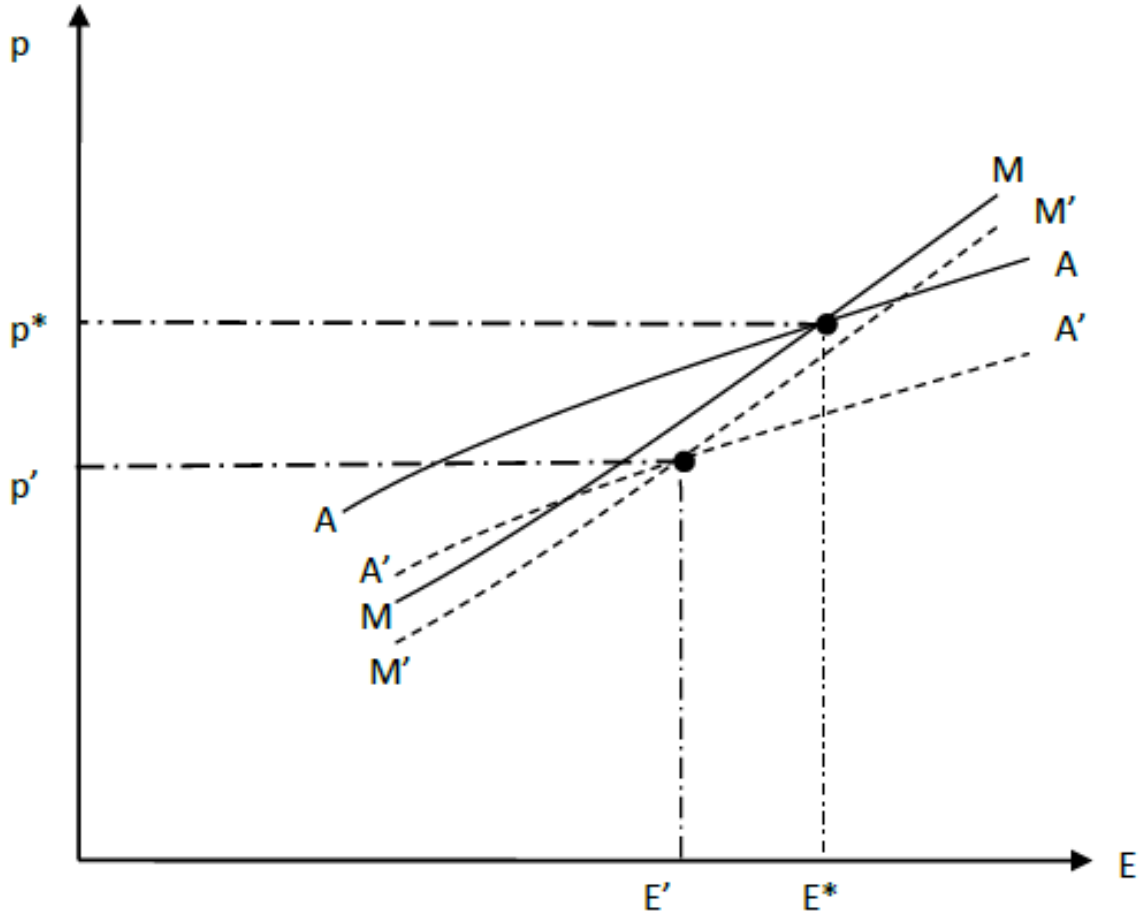

Figure 5: The effects of an increase in agricultural productivity

Government Expenditures

- Under the stability condition, an increase in government expenditure increases urban employment and raises agricultural prices and incomes
  - In figure 6, 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

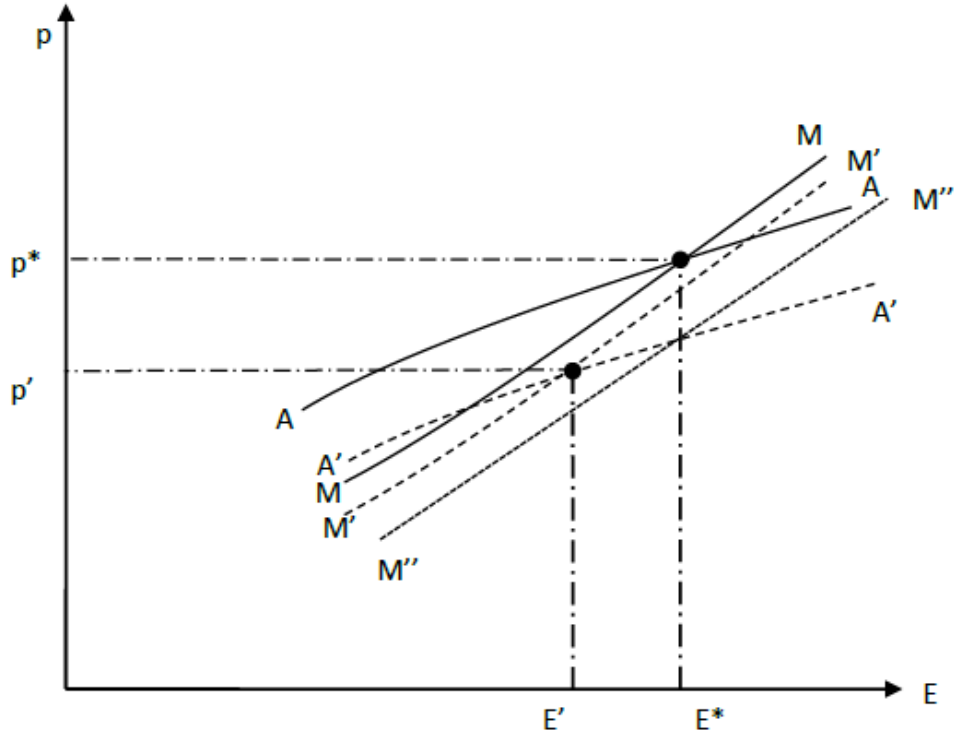

Figure 6: Impact of Keynesian stimulus:
an increase of G shifts the MM curve from M'M' to M''M''
and increases both employment and rural prices

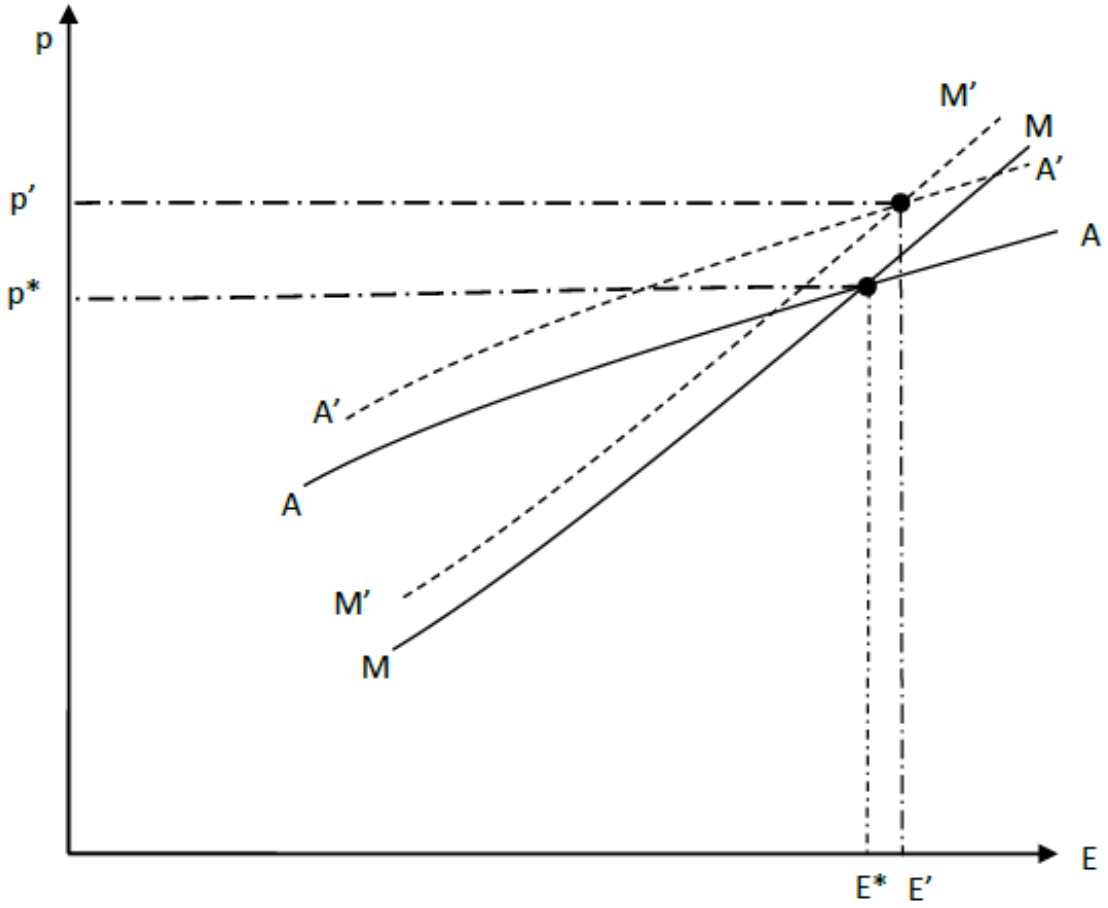

Figure 7: Effects of Migration Subsidy

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*

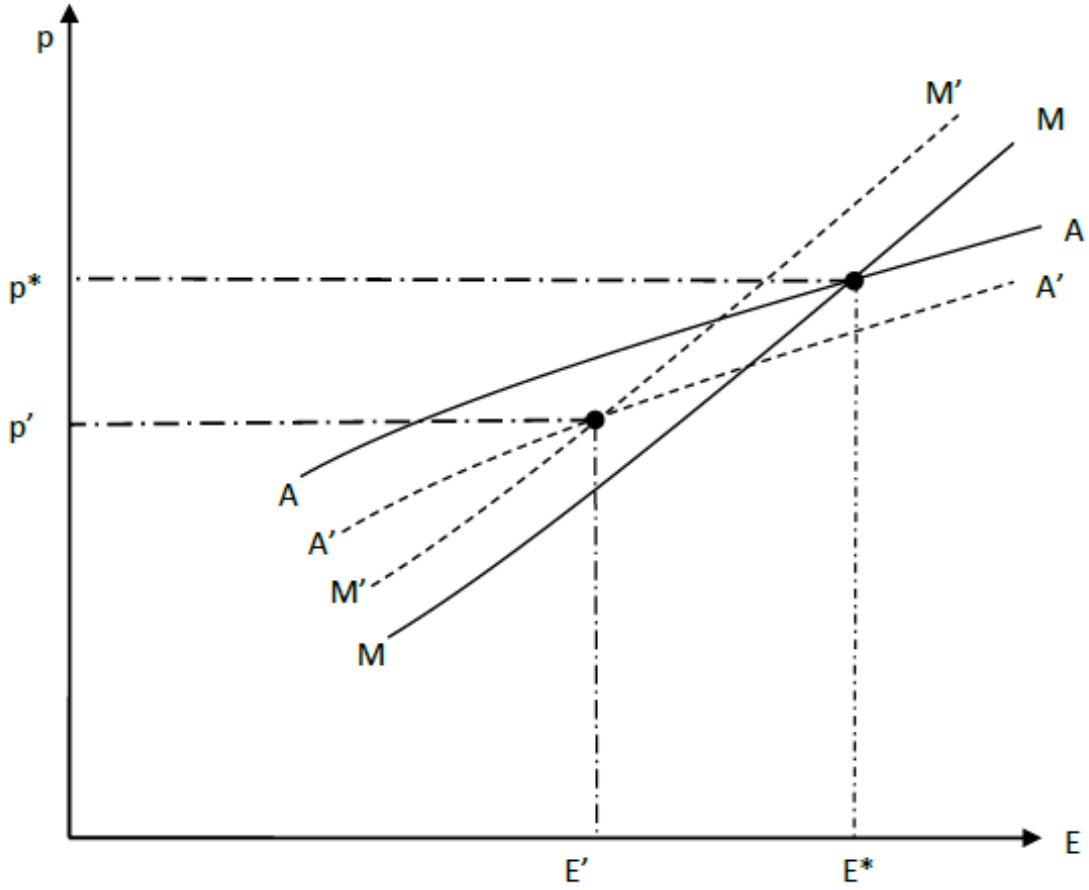

Figure 8: The effects of downward wage adjustments

VII. 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 λ, taking into account the effect of λ on the unemployment rate:

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

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

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

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

VIII. 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

Λ 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, κ:

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

Can solve for Λ as a function of κ:

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

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

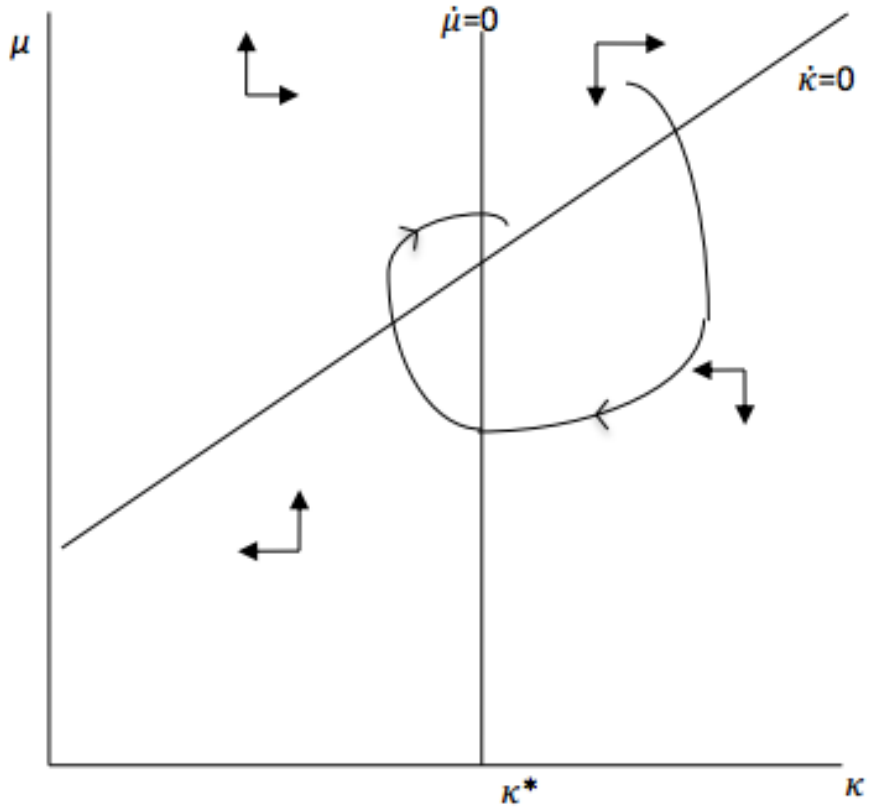

Figure 9

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)