Monetary Policy in the Age of Automation

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Motivation and research questions

- Technological progress often takes the form of automation (capital replacing labor in performing tasks)
- Active debate about the implications for monetary policy
  - Is automation deflationary?
  - Can automation generate technological unemployment?
  - Sharp monetary tightening: lower automation and productivity?
- But little academic research on these topics

This paper

- Standard model of automation (Acemoglu & Restrepo, AER)
  - Capital and labor are highly substitutable in performing some production tasks
  - Macroeconomic conditions affect firms' adoption of automation technologies
- Two new features
  - Nominal wage rigidities → monetary policy has real effects
  - Discounted Euler equation → long-run IS curve (Eggertsson, Mehrotra and Robbins, 2019; Michaillat and Saez, 2021; ...)

Preview of results

- Automation effect of monetary policy
  - Traditional view: monetary tightenings lower employment/inflation
  - Our view: monetary tightenings may reduce automation and labor productivity (even permanently)
- Central bank may face a trade-off between employment and automation
  - When aggregate demand is persistently weak
  - When new automation technologies are introduced

Sketch of the model - Households

- Households' demand for consumption

$$C = \frac{1 - \beta(1+i)/\pi}{\xi}$$

- No arbitrage between bonds and capital

$$\frac{1+i}{\pi} = 1 + r^k - \delta$$

- Desired labor supply $\bar{L}$
  - $L = \bar{L}$ full employment (flex. wages)
  - $L < \bar{L}$ involuntary unemployment
  - $L > \bar{L}$ overheating

Production

- Final good produced using a continuum of inputs (or tasks)

$$\log Y = \int_0^1 \log y_j dj$$

- Inputs $j \leq J^l$ can be produced with capital only

$$y_j = \gamma^k k_j$$

- Inputs $J^l < j \leq J^h$ can be produced using capital or labor

$$y_j = \gamma^k k_j + \gamma^l l_j$$

- Inputs $j > J^h$ can be produced using labor only

$$y_j = \gamma^l l_j$$

- J^h captures technological constraints on automation

Factor prices and automation

- Aggregate production function

$$Y = \left(\frac{\gamma^k K}{J^*}\right)^{J^*} \left(\frac{\gamma^l L}{1 - J^*}\right)^{1-J^*}$$

- Define J^* such that all intermediate goods with $j \leq J^*$ are produced with capital, the rest with labor

  1. If $r^k/\gamma^k > w/\gamma^l$ then $J^* = J^l$ (low automation)
  2. If $r^k/\gamma^k = w/\gamma^l$ then $J^* \in [J^l, J^h]$ (intermediate automation)
  3. If $r^k/\gamma^k < w/\gamma^l$ then $J^* = J^h$ (high automation)

- Low cost of capital, relative to wages, implies more automation

Nominal rigidities and monetary policy

- Wage Phillips curve ($\psi < +\infty$)

$$W_t = \left(\frac{L_t}{\bar{L}}\right)^{\psi} W_{t-1}$$

- Price of final good

$$P = \left(\frac{r^k}{\gamma^k}\right)^{\frac{J^*}{1-J^*}} \frac{W}{\gamma^l}$$

- By setting i, monetary policy controls the real rate $r \equiv i - \pi$ and aggregate demand

$$Y = C + \delta K$$

The automation effect

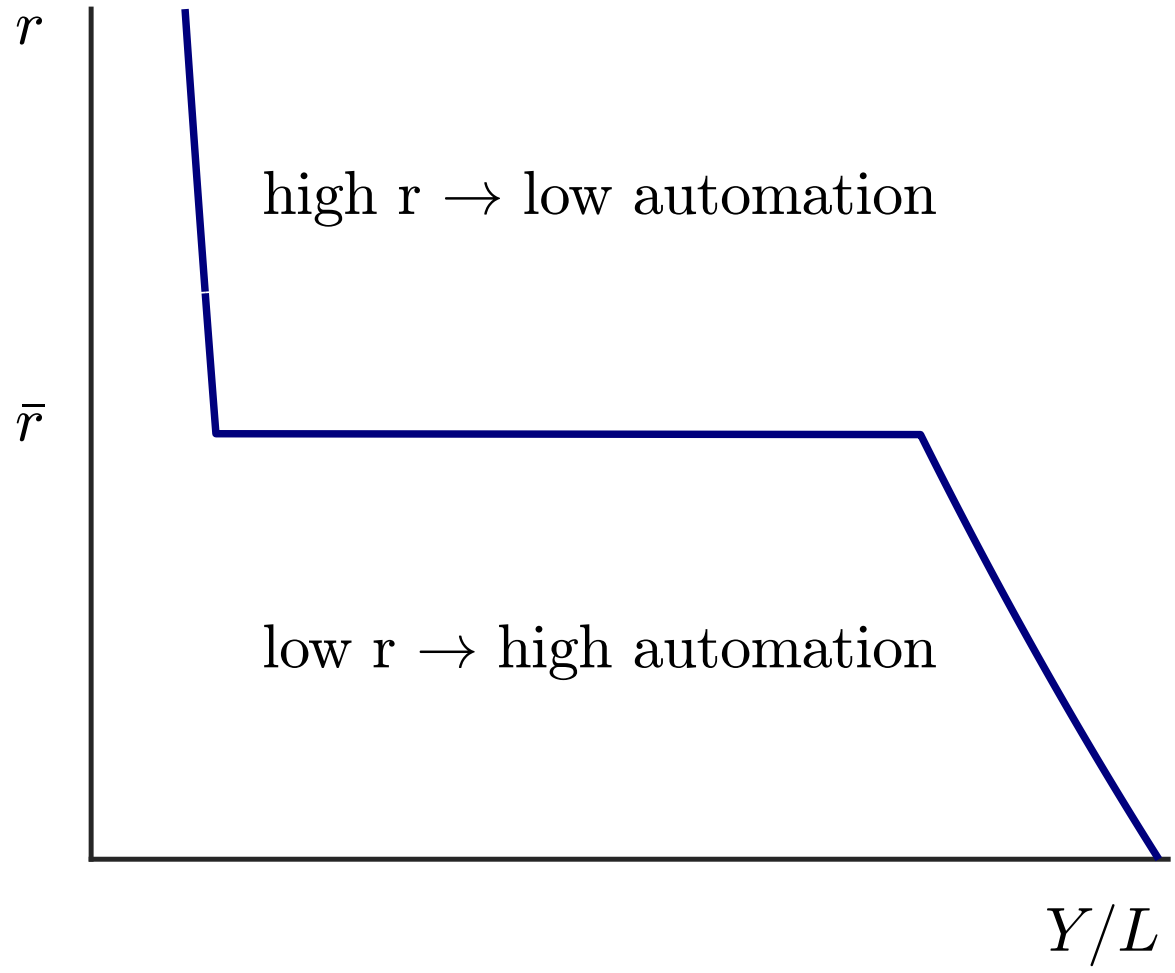
- Interest rate determines cost of capital ($r = r^k - \delta$) and so firms' use of automation technologies
  1. If $r > \bar{r}$ then $J^* = J^l$ (low automation)
  2. If $r = \bar{r}$ then $J^* \in [J^l, J^h]$ (intermediate automation)
  3. If $r < \bar{r}$ then $J^* = J^h$ (high automation)

- Drop in r may generate switch from low to high automation, which boosts investment and labor productivity

$$\frac{Y}{L} = \underbrace{\frac{\gamma^l}{1 - J^*}}_{\text{automation}} \underbrace{\left(\frac{\gamma^k}{r + \delta}\right)^{\frac{J^*}{1-J^*}}}_{\text{capital deepening}}$$

- Automation effect is a distinguishing feature of our framework

The productivity effect of automation



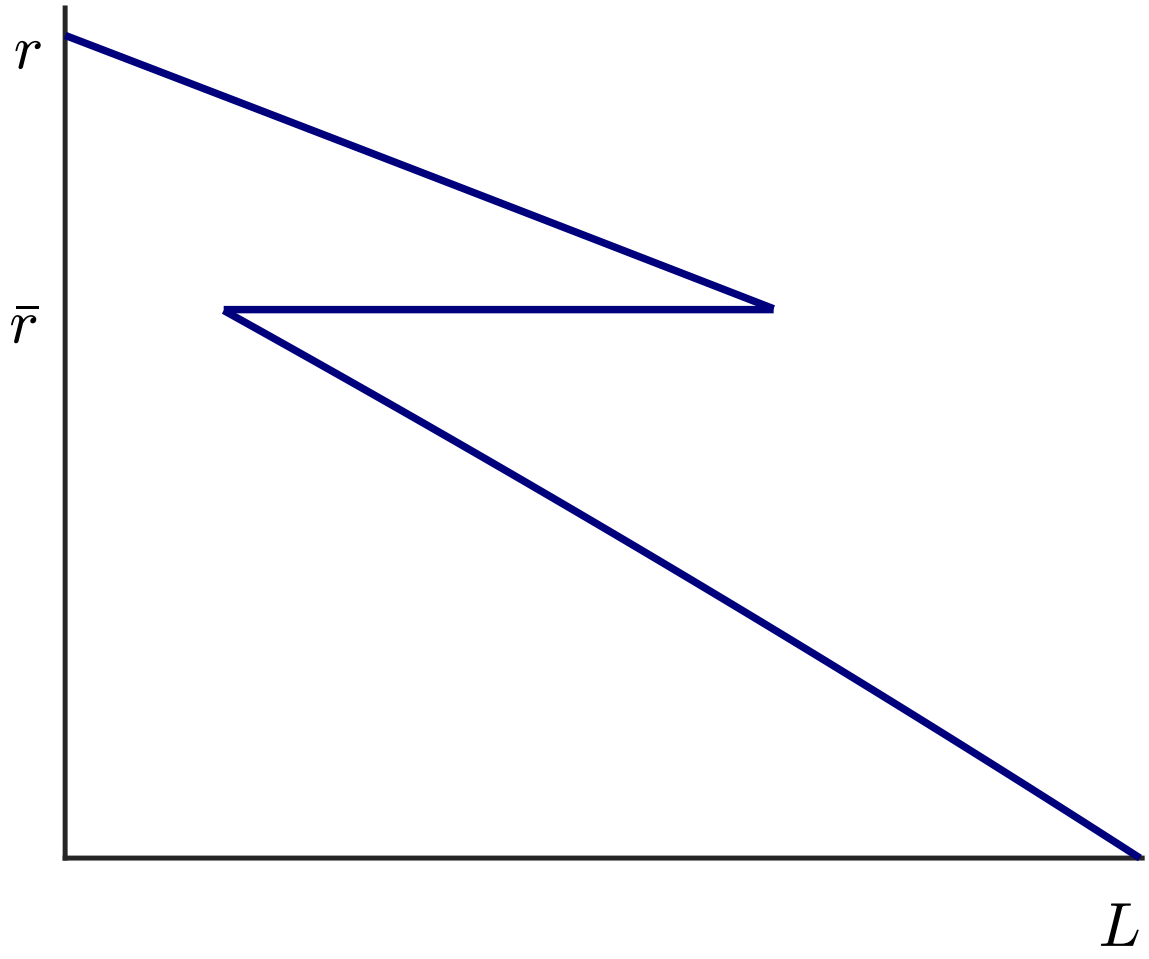
The labor demand curve

- Labor demand in steady state

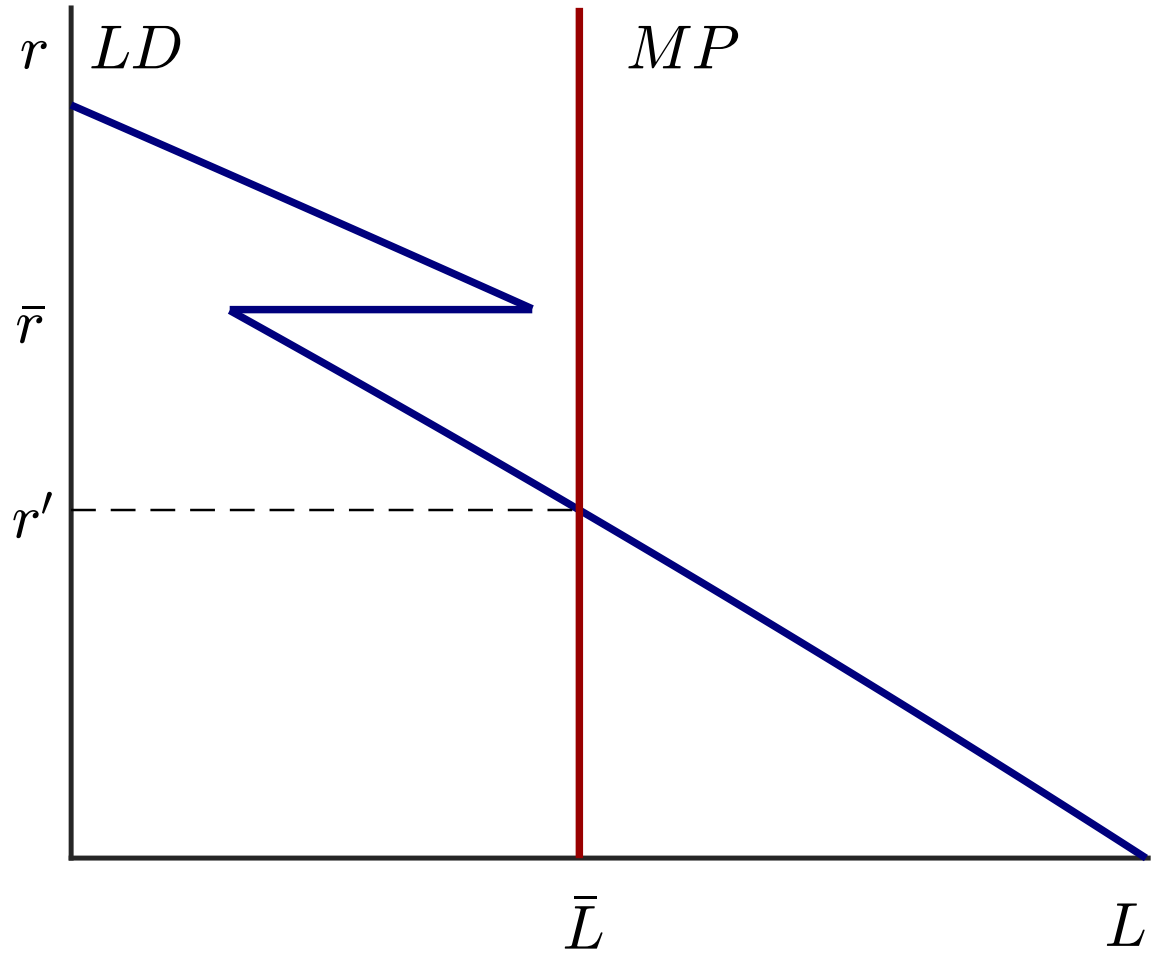
$$L = \underbrace{\frac{L}{Y}}_{\text{labor productivity}} \underbrace{Y}_{\text{aggregate demand}}$$

- How does monetary policy affect employment?
  - Aggregate demand: $\downarrow r$, $\uparrow Y$, $\uparrow L$
  - Automation: $\downarrow r$ may lead to $\uparrow J^*$, large $\uparrow Y/L$ and $\downarrow L$

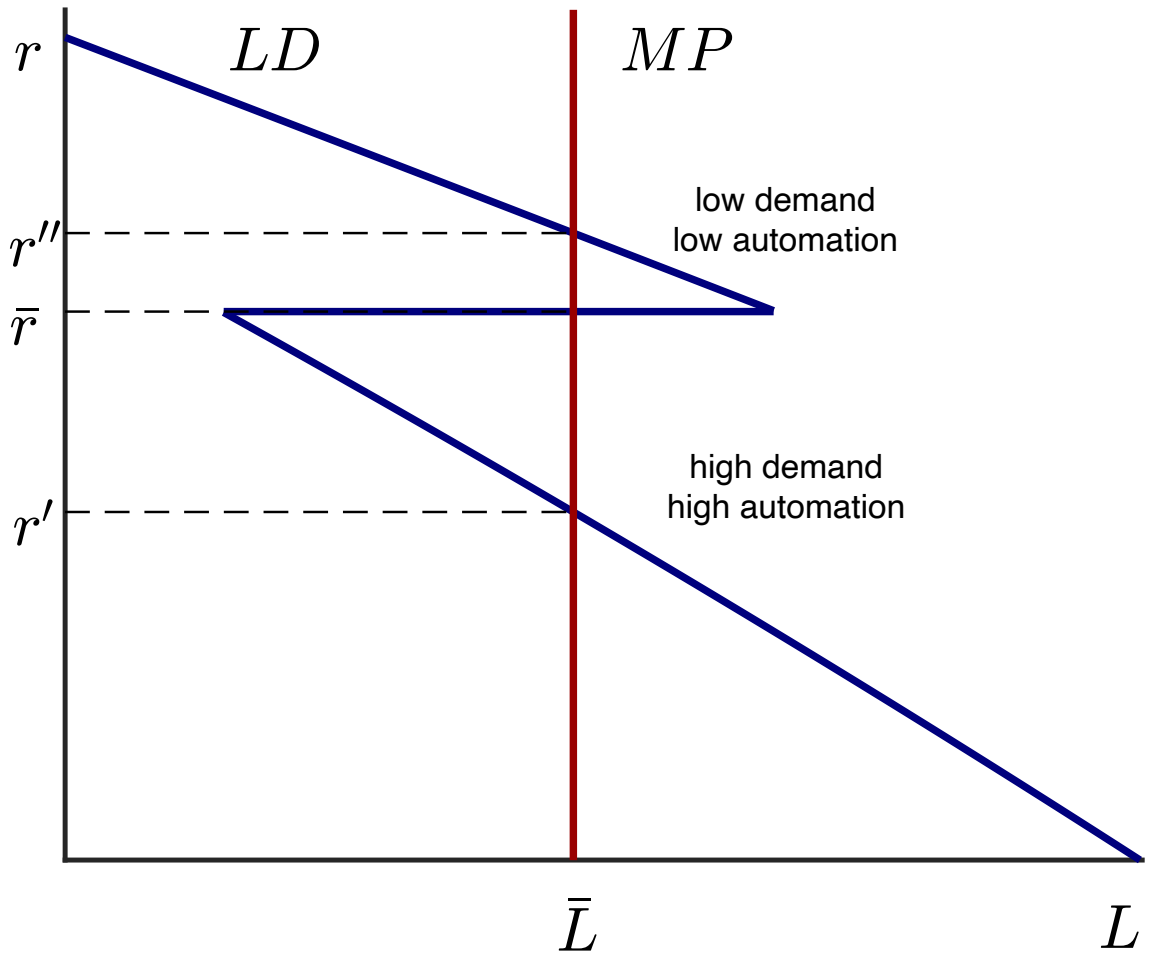
The labor demand curve



Unique full employment steady state



Multiple full employment steady states

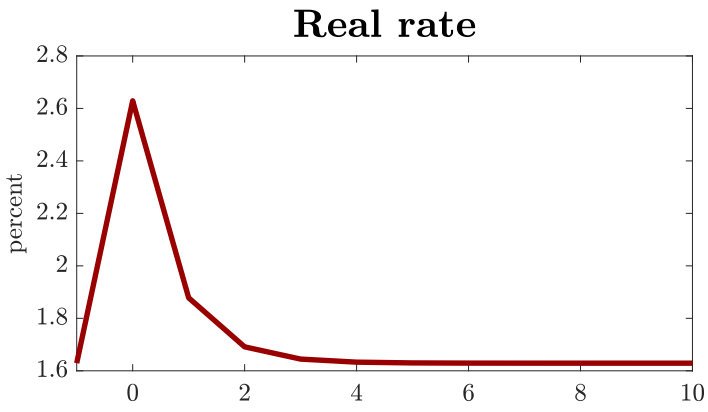


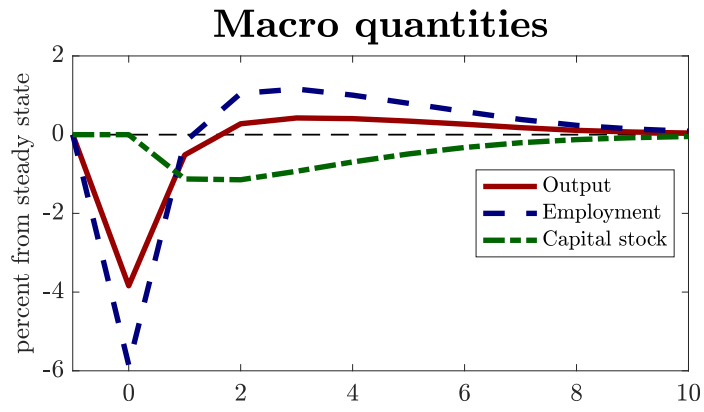
Summary of results

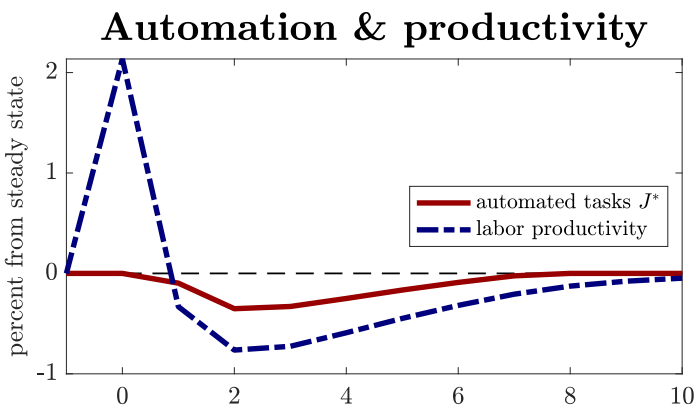
smooth technology

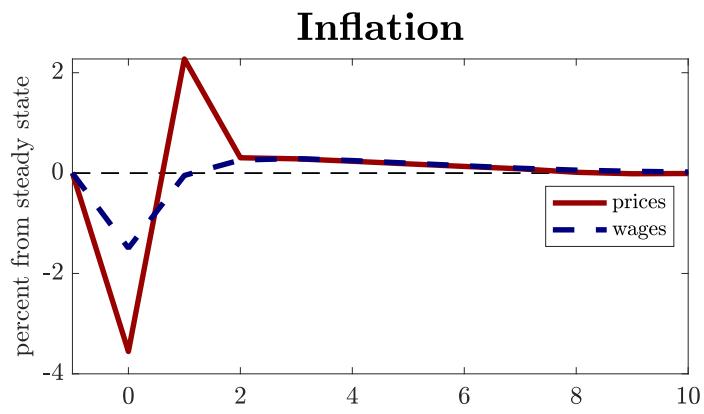
- A monetary expansion raises aggregate demand, but may also induce firms to automate their production
  - Higher automation raises investment, the capital stock, labor productivity and therefore wages
  - When the automation effect is strong enough, labor demand may decline after a monetary expansion
- Through this effect, there can be multiple steady states where employment equals its natural level and inflation is at target

A temporary monetary tightening



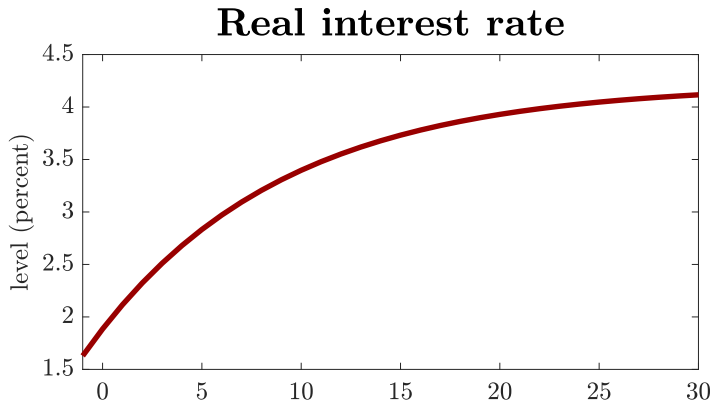


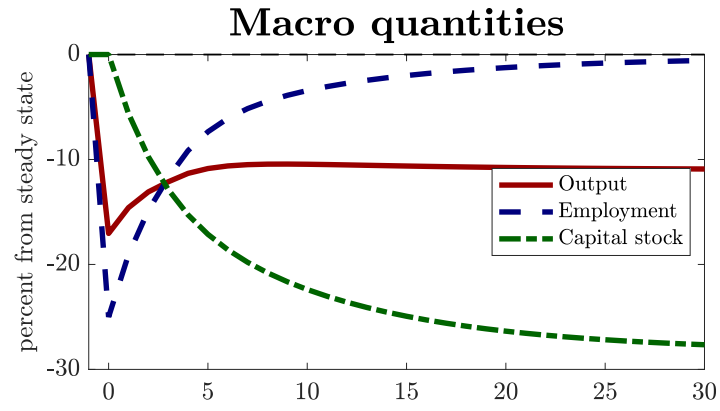


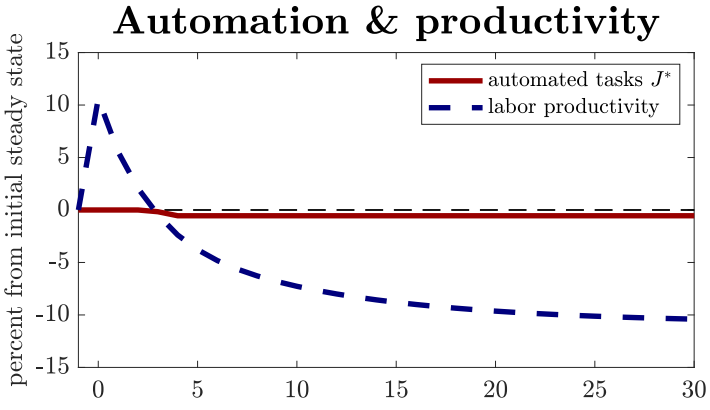


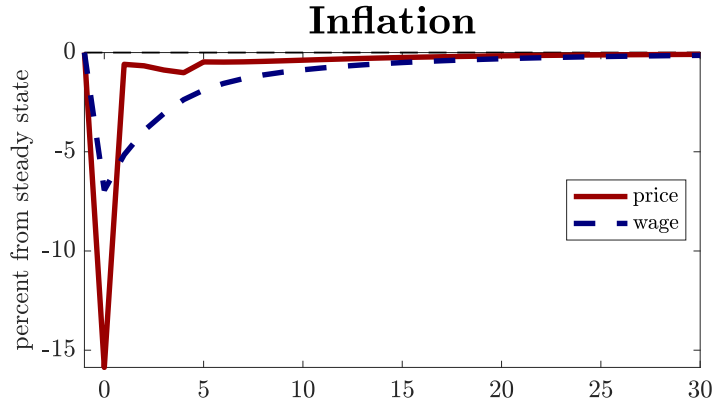
- Temporary drop in employment, persistent drop in productivity
- Inflation initially falls and then rises

Long-run effects from monetary tightening



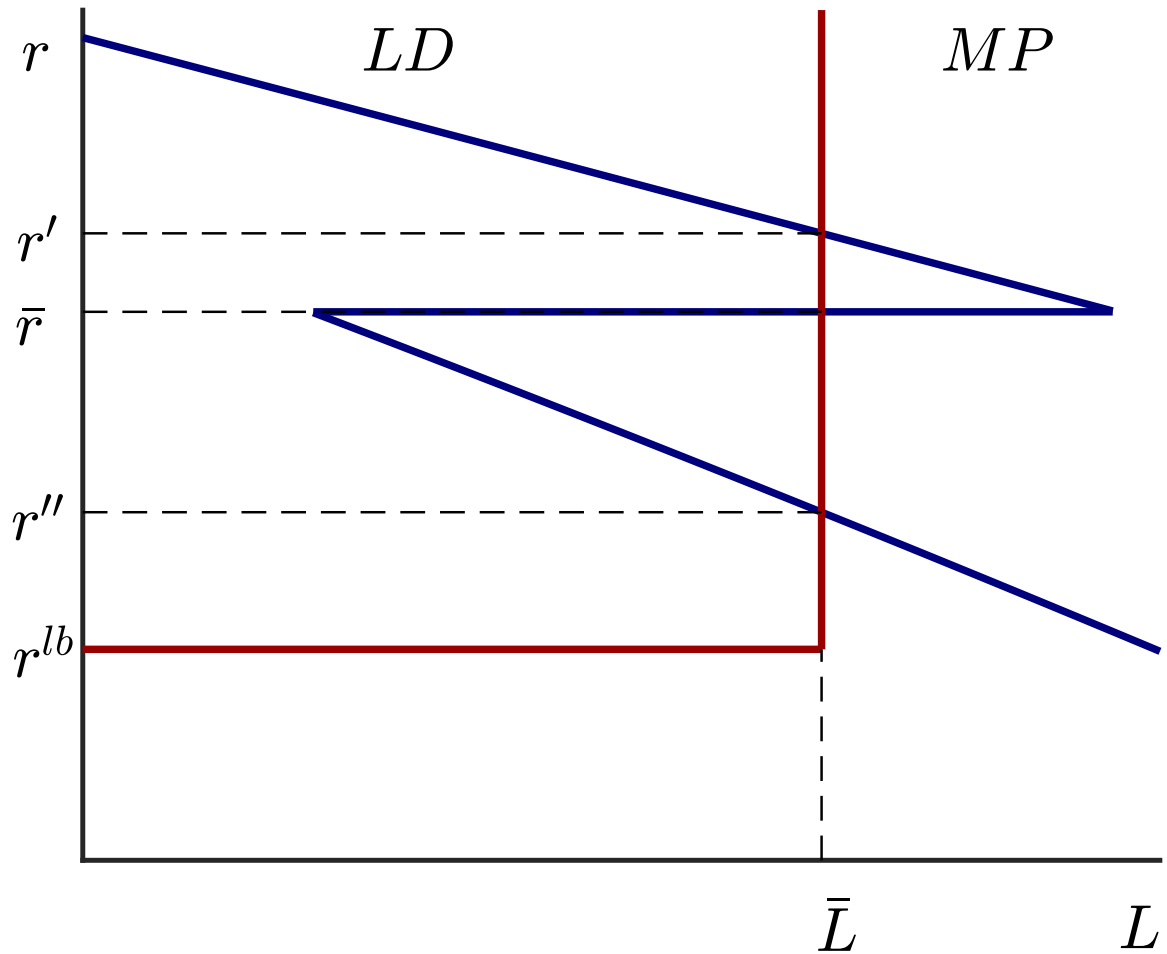




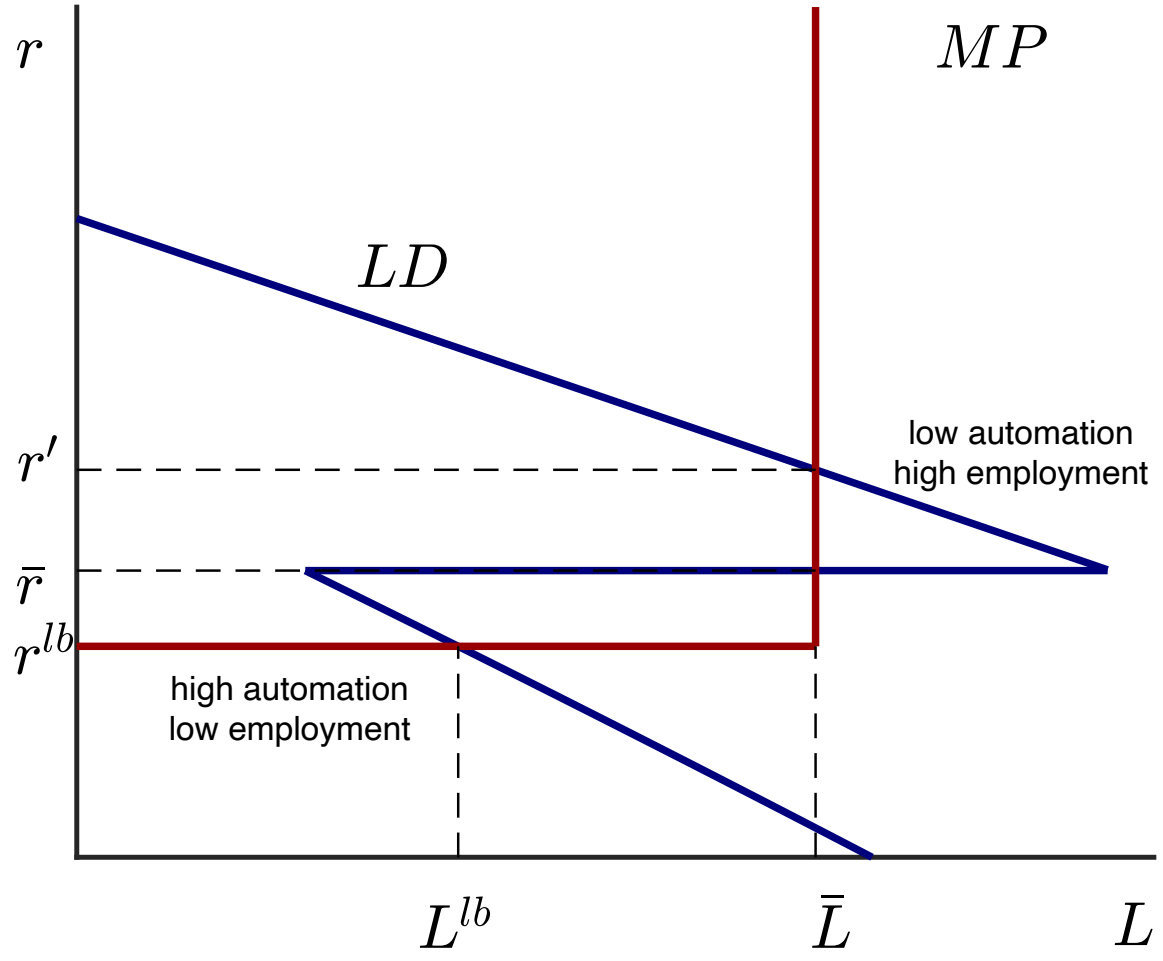


- Temporary disinflation $\rightarrow$ long run drop in automation and productivity

High-demand economy



Persistent drop in demand (↑ preference for liquidity)



A new trade off for monetary policy

- If demand is too low, the high automation steady state with employment at its natural level is no longer attainable
- Trade off between employment and automation?
  - High automation steady state features involuntary unemployment and deflation
  - Full employment can be sustained only through a process of de-automation, leading to low productivity
- Link to UK productivity puzzle (Sandbu, 2020)
  - Weak productivity growth in the UK in post-crisis slump
  - Reduction in K/Y

Rise in automation $\uparrow J^h$

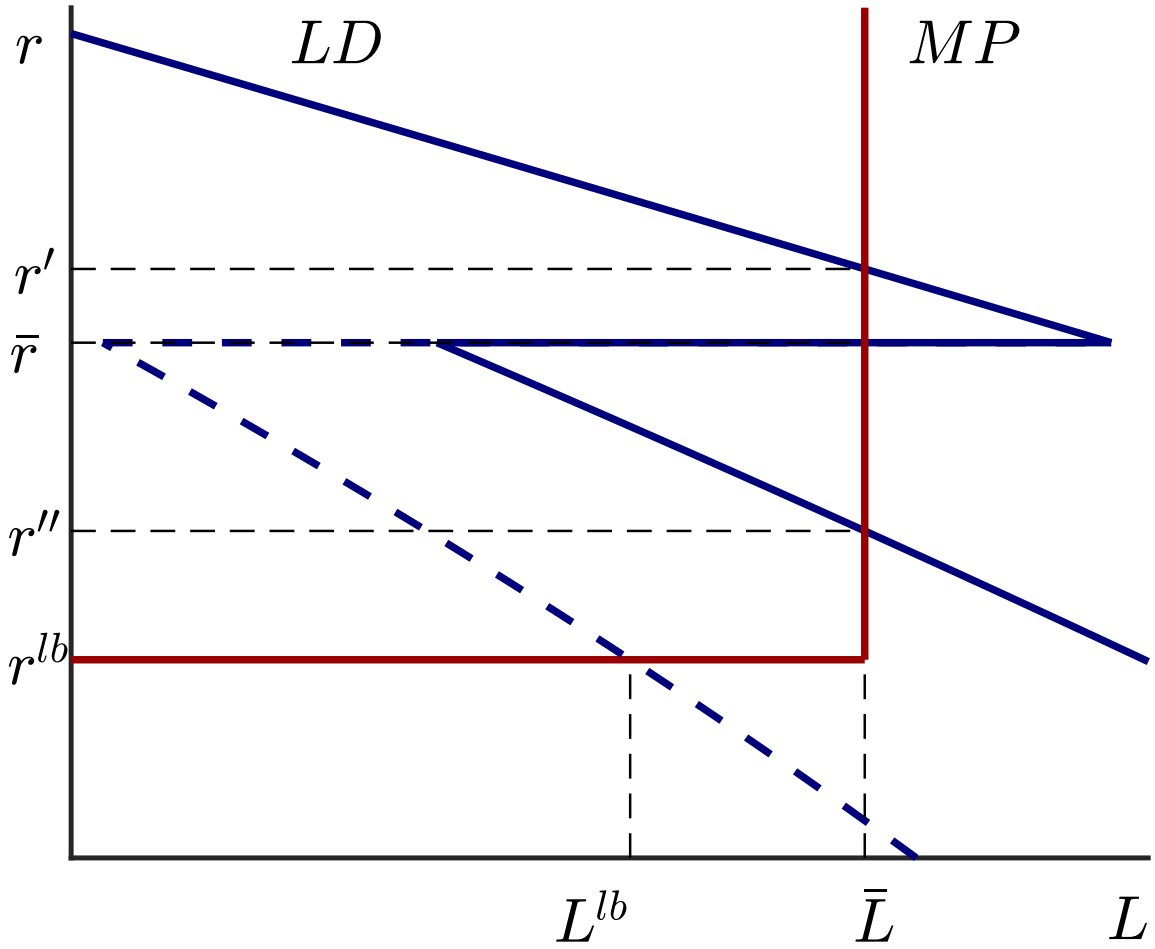


Figure: Rise in automation. Notes: solid LD line denotes low J^h, dashed LD line denotes high J^h.

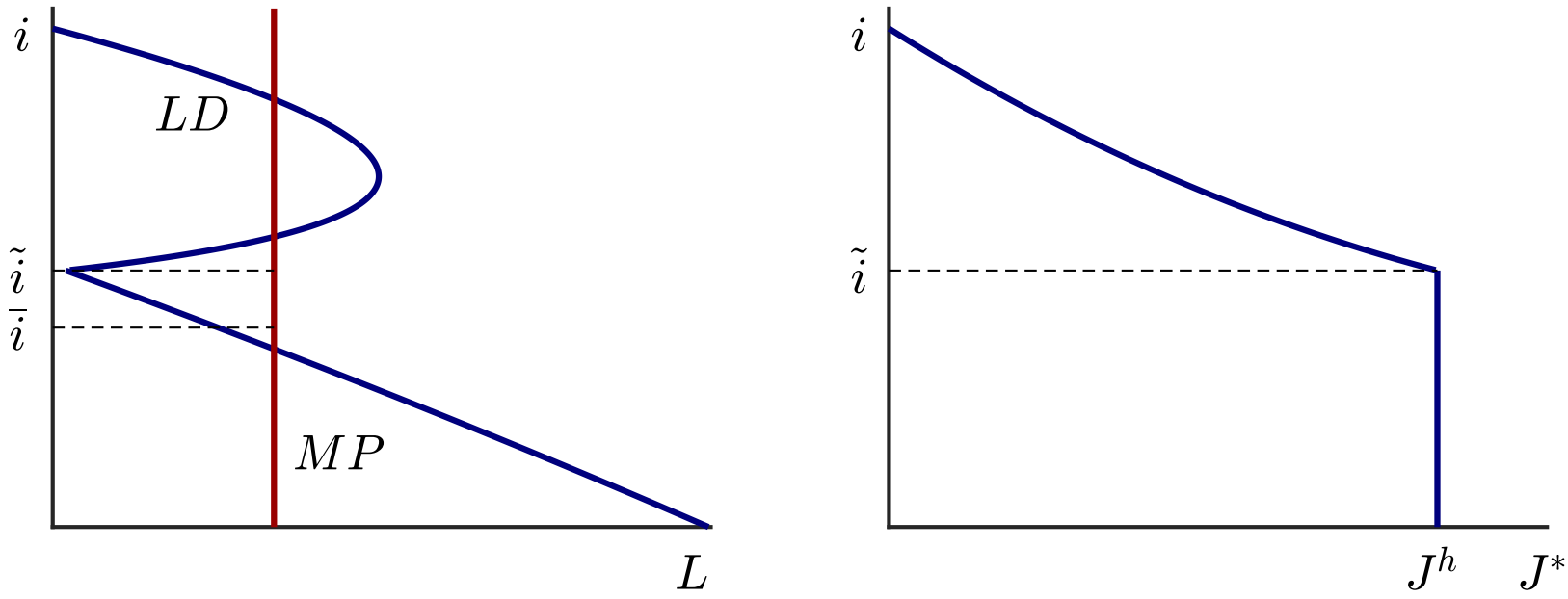
More automation may require expansionary policies

- Suppose that the scope for automation increases ($\uparrow J^h$)
  - To maintain the economy at full employment, the central bank may need to cut interest rates
  - Rise in automation technologies can generate a liquidity trap with involuntary unemployment (Keynes, 1930)
- Against a background of weak demand, a rise in automation can even be welfare reducing by displacing labor

Conclusion

- Besides employment and inflation, monetary policy may affect use of automation and productivity
- Monetary actions may have a transitory impact on employment and inflation, while persistently affecting automation and productivity
- Weak aggregate demand may show up in de-automation and low labor productivity
  - Technological impact of secular stagnation
  - Trade off between automation and employment
- Rise in automation may displace labor, if macroeconomic policies cannot effectively support demand

Model with smooth technology back



(a) Labor demand. **(b) Degree of automation.**

Figure: In this model, the productivity of labor $\gamma^l(j)$ varies smoothly in task-index j, as in Acemoglu and Restrepo (2018).